11-16-1987

Comparison of color lightness in two-color plus black reproduction systems vs. three-color reproduction systems

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With a major in Printing Technology
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December 1987
date

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Comparison of Color Lightness in Two-Color Plus Black Reproduction System vs. Three-Color Reproduction System

by

Lonnie Jackson

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in the School of Printing
in the College of Graphic Arts and Photography
of the Rochester Institute of Technology

November 16, 1987

Thesis Adviser: Dr. J. Silver

ACKNOWLEDGEMENTS

I would like to thank those people who deserve credit for helping me to complete this thesis.

The research, testing and manuscript typing was done at Rochester Institute of Technology's School of Printing facilities. For that reason, I would like to thank the School of Printing faculty at RIT.

I would also like to express my gratitude to Dr. Julius Silver for the topic and his support on the project throughout its development and completion.

Finally, a special thank you to my family for their guidance and encouragement.

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ABSTRACT

A theory that has existed since 1948 has just recently gained wide acceptance from the printing industry. The recent technological advancements in electronic scanners has made it feasible for color separations to be scanned implementing Gray Component Replacement (GCR). Eventhough most of the electronic scanners today have GCR capabilities, some questions regarding GCR and its implementation have gone unanswered.

In an attempt to help resolve this problem, this paper investigated the issue of lightness characteristics associated with GCR reproductions. In particular, this paper attempted to prove that, by replacing a graying component of a conventional reproduction made up of three transparent inks with a black ink in proportional amounts, less light would be scattered within the paper and trapped by the ink due to less ink coverage. Accordingly, the less light trapped under the ink, the closer that reproduction would be to the original in lightness.

The results of the experiment proved that GCR is not as simple as some believed it to be. In addition, two experimental errors made it difficult to support the hypothesis.

CHAPTER ONE

INTRODUCTION

Gray component replacement (GCR) is a topic of great interest in the printing industry today. Although the theory is old, GCR has just recently become a practical reality to color separators. This fact is mainly due to the recent development of electronic scanners.

There are several attributes that are said to be inherent in the GCR process: reduced ink consumption, shorter makeready, less hue shift during a press run, fewer register problems, better results on low quality paper and a reproduction that is a closer lightness match to the original than the conventional three-color printing system. Lightness can be defined as the extent to which a material appears to reflect incident light. Brightness is sometimes used to subjectively describe a color's lightness - one color is brighter than another. However, lightness is used when objectively describing a color.

If this process does in fact have these attributes, then it would be beneficial to the printer to adopt the GCR process. There are a lot of printing professionals who think that this process will be adopted by most, and they estimate that within a few years, 80% of all separations will be done implementing GCR.

The ultimate goal in any reproduction process is to match the original. However, since a facsimile reproduction is impossible in the printing process, the printers try to get as close as possible to the original. Obviously, if a reproduction process is developed that allows the printer to get a closer match to the original, then it would be advantageous to utilize this process.

This research will investigate the use of substituting a graying component of a color with a black ink, and then determine the degree of light scattering which takes place in each sample. When one sample scatters and traps less light than another sample, it will be a closer lightness match to the original. Consequently, in this experiment, closer lightness match will be defined as that sample which scatters and traps less incident light. Further, the sample with the lower "n" value, as defined by the Yule-Nielsen Equation, is said to scatter and trap less incident light.

CHAPTER TWO

BACKGROUND

Black Printer

Originally, the subtractive color theory used three transparent inks, yellow, magenta and cyan, to produce any color combination from a color original. In fact, even today, there are a few printers reproducing satisfactory colors with only the three transparent inks. It would seem that the introduction of a black printer into a predominately three color scheme would darken the picture and produce a muddy appearance, and this is just what happens unless corrective measures are applied.[1] These corrective measures include undercolor removal (UCR), making room for the black by reducing the amount of the other three colors wherever black is to be printed.[2]

There are four main reasons for using a black printer.

(1.) To make the control of the other three colors less critical as to ink balance.

(2.) To produce denser blacks and better shadow detail than the other three colors alone can produce.

(3.) To substitute a relatively inexpensive black ink for a part of the more costly colored inks.

(4.) In high-speed wet printing, to avoid the piling up of several inks which do not print satisfactorily on top of each other.[3]

In color printing, there are basically two types of black printers that are used in conjunction with the three primary process colors. The first type is a black printer that carries only enough ink to make the dark grays more gray. This is the black printer the industry prefers to call the skeleton printer. It serves mainly to improve shadow detail and density, usually adding ink where the overprints of the three process colors have reached there maximum. This is illustrated in Figure 1.

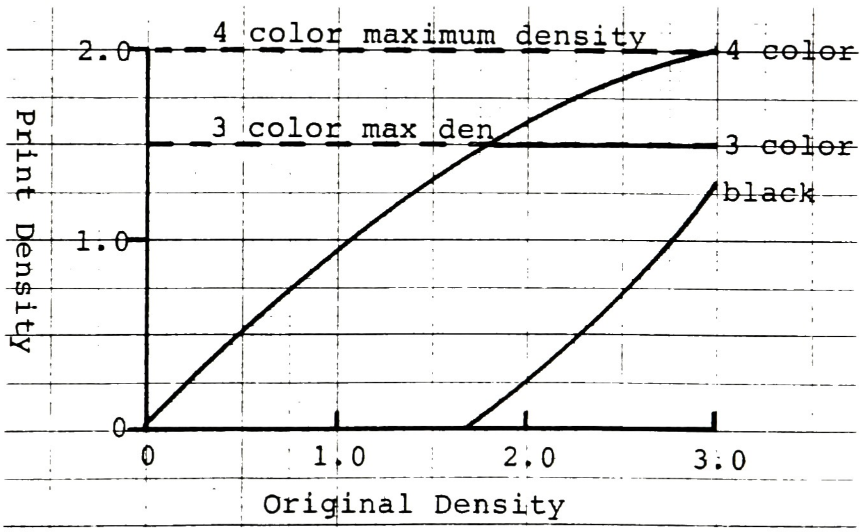


Figure 1. Skeleton black printer.

The second type of black printer is the one with which this experiment is concerned. This printer carries the maximum amount of black ink and can be combined with not more than two of the three subtractive primaries in any one unit area of the print. A unit area may be defined as any place on the reproduction where there is at least one printing dot of each color that is necessary to reproduce that hue. This type of black printer will be a record of the gray component of the original. This printer does not print in the midtone to shadow areas only, as does the skeleton printer, but extends to all areas of the reproduction that contain a graying component, as shown in Figure 2. Here, the maximum amount of black ink has been

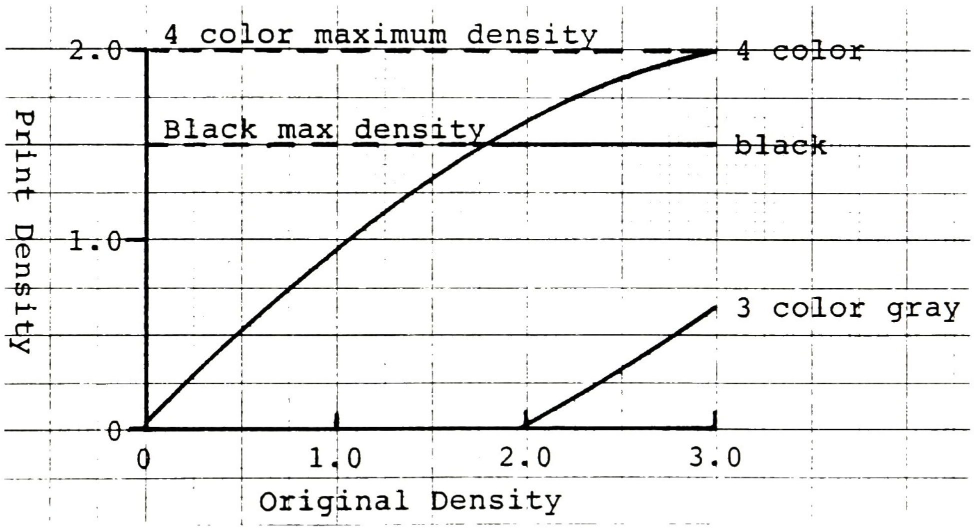


Figure 2. Black printer carrying maximum amount of black ink.

used. Each unit area is printed with only two transparent inks plus black (as in 100% GCR). It should also be pointed out that in the dark shadow areas of the reproduction, a three color gray has to be reintroduced, since black alone can not produce the maximum shadow density needed.

Color Theory

Color theory is quite complex and beyond the scope of this thesis. However, it is necessary to provide the basics here for a clear understanding of the problem under investigation.

Three things are necessary for color to exist: a light source, a colored object and a detector. A light source is necessary to provide illumination to the object. Absence of light is total darkness and color can not be perceived in total darkness.

The colored object is simply a material which when illuminated reflects certain wavelengths of the spectrum.

The detector is what perceives or interprets this color. The detector can be any number of things, the most common detector is the human eye.

When a colored object is illuminated by light, the light which is reflected at certain wavelengths of the visible spectrum determines the color of that object. The visible spectrum is that part of the electro-magnetic spectrum to which the eye is sensitive. This is illustrated in Figure 3. The visible spectrum ranges from 380 nanometers to 750 nanometers and is usually divided up into three equal broad bands: the blue band ranging from 400nm to 500nm; the green band ranging from 500nm to 600nm; and the red band ranging from 600nm to 700nm. Color is

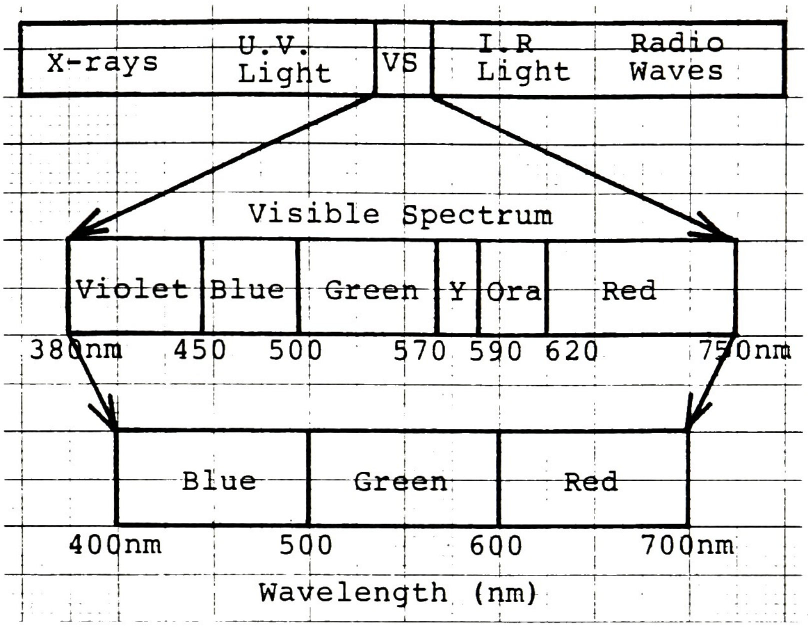


Figure 3. Visible spectrum portion of the electro-magnetic spectrum.

perceived by sensing varying amounts of these three bands.

Colors have three main attributes: hue, saturation and lightness. A color's hue can be determined by the dominant

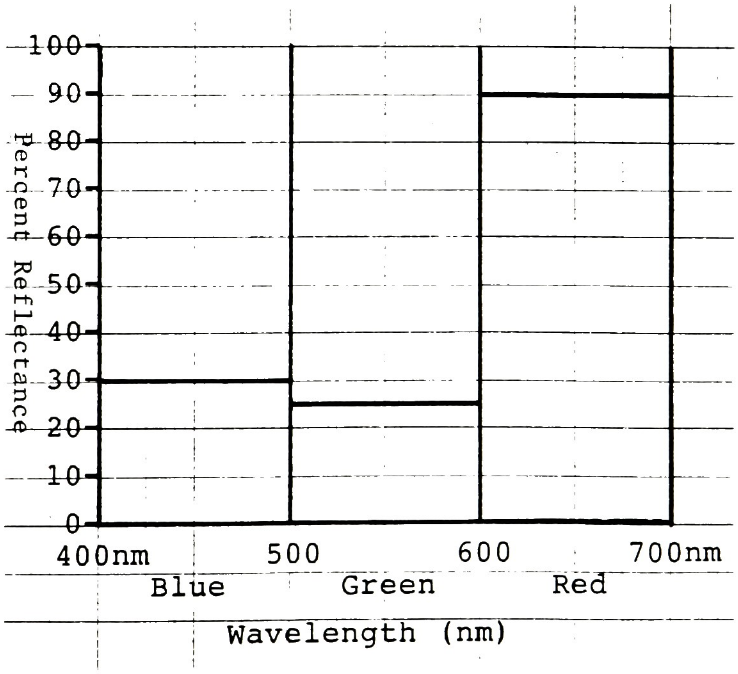


Figure 4. Reflectance curve showing dominant wide band reflectance of the red band.

band of the reflectance curve. Reflectance curves are used to illustrate the amount of light being reflected from each broad band of the visible spectrum.[4] This is illustrated in Figure 4. In Figure 4, 30% of the blue band is reflected; 25% of the green band is reflected; and 90% of the red band is reflected. The color perceived here would have a red hue.

Saturation, the second attribute of color, can be defined as a measure of how much that dominant band is diluted or mixed in with the other bands.[5] A perfectly saturated color would be one that had zero percent reflectance at two of the three wide bands and some reflectance at the other wide band.

Lightness is the third attribute of color. It denotes the intensity to which a material appears to reflect

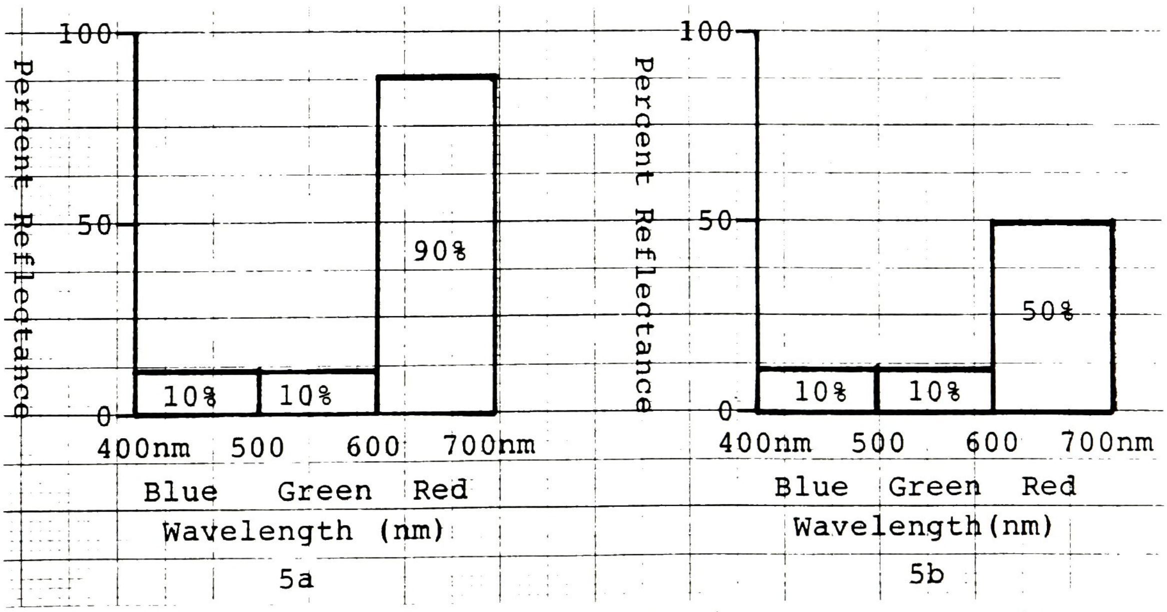


Figure 5. Reflectance curve showing two colors with same hue and saturation but different lightness.

light. It is the atrribute by which one surface is judged to reflect a greater or smaller proportion of incident light than another.[6] Two colors may have the same hue and saturation and differ only in lightness, as illustrated in Figure 5. Here both colors have the same hue (red) and the same saturation; however, the red color in Figure 5b is lower in lightness than the red color in Figure 5a. It is reflecting less incident light than Figure 5a.

Lightness is the attribute of color under investigation in this thesis. In this study, lightness has been defined as the extent to which a material appears to reflect incident light. Inks transmit light, while it is the paper that serves to reflect the light.

It is the use of the process colored inks that controls the amount of light that will be reflected by the substrate. Yellow ink absorbs the blue band; magenta ink absorbs the green band; and cyan ink absorbs the red band. Further, the amount of light that is absorbed is determined by the size of the printed dots. To absorb ten percent of the blue band, 20% of the green band and 80% of the red band, a ten percent yellow dot, a 20% magenta dot and an 80% cyan dot would need to be laid down in a unit area of the paper. This would leave 90% of the blue band, 80% of the green band and 20% of the red band to be reflected.

Ink Deficiencies

An ideal set of process colored inks would absorb 100% of one band and transmitt 100% of the other two bands, based on 100% ink coverage. However, the inks that are used today are not ideal. Typical inks partially absorb light that should be transmitted and transmit light that should be absorbed. For example, the cyan ink absorbs not only red light but also some green and blue light. The magenta ink absorbs not only green light but also some blue and red light. The yellow ink is closest to ideal and absorbs only a little of the green and red light.

Gray Component

A gray component is perceived when the three broad bands of the visible spectrum are reflected equally. Figure 6 shows a gray component of a unit area with 80% reflectance from each of the three broad bands. With ideal inks, a 20% yellow dot, a 20% magenta dot and a 20% cyan dot would yield this graying component. However, with a typical set of inks, it may be necessary to laydown a 14% yellow dot, a 15% magenta dot and a 17% cyan dot to achieve 80% reflectance of each of the three broad bands.[7]

Theoretically, the black ink is a total light absorber. Depending on the amount of black applied, each of the three

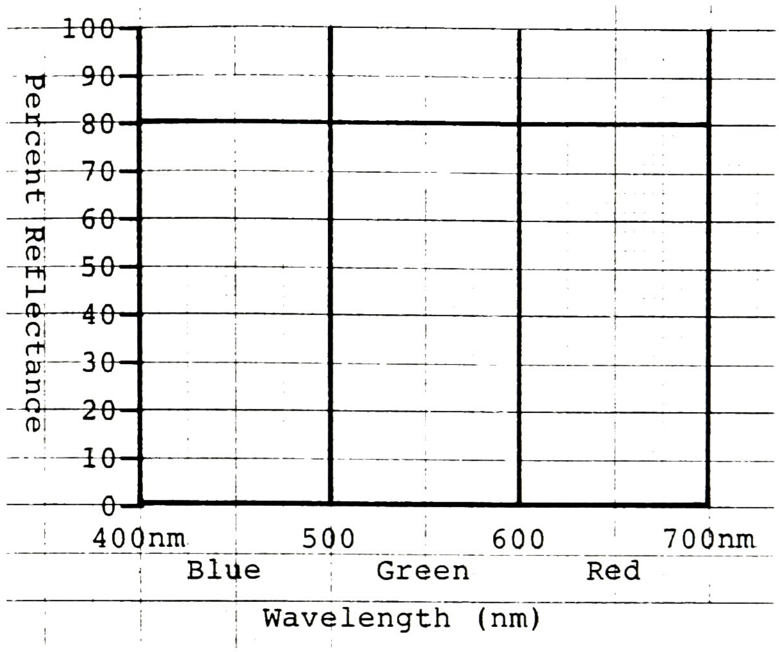


Figure 6. Reflectance curve showing a gray component.

broad bands will be absorbed equally. If a 20% black dot was used, then 20% of each band would be absorbed, leaving 80% of each band to be reflected. Therefore, this 20% black dot would produce the same graying component as the three process colored dots represented in Figure 6. There is no need to use three process colored inks to produce a gray component when the black ink could perform the same function. However, as discussed earlier, it may be necessary to print a three color gray in addition to the black in the dark shadow areas to achieve maximum density.

Density

The lightness of a color depends on the amount of light that is transmitted through the inks and reflected from the substrate, as stated earlier. Further, the reflectance of a unit area is the ratio between the amount of light reflected from a given tone area and the amount reflected from a white area on the same paper. Thus, if an image area reflects one fourth the portion of light that would be reflected by a white area, then the reflectance of the image area is 0.25. Since reflectance is a measure of the amount of light reflected by the image area, the numbers are higher for lighter images and lower for darker images.[8]

In order to describe the amount of light held back, the term opacity is introduced. Opacity is defined as the reciprocal of reflectance, therefore the opacity numbers become larger as the image areas get darker. Furthermore, density can be defined as the logarithm of opacity, or the logarithm of the reciprocal of the reflectance.[9] Opacity $=1/R$ and density$=\log 1/R$. A unit area with a density of 1.00 reflects ten percent of the incident light; a unit area with a density of 2.00 reflects one percent of the incident light, and so on.

A densitometer can be used to measure the density of a unit area in the reproduction. A densitometer consists of a light source that illuminates the copy at an angle of 45 degrees. Some part of the incident light is reflected from the copy into a light-sensitive photocell in a 90 degree position from the paper surface. This 90 degree positioning of the light-sensitive photocell simulates the human eye viewing position. Only the light that is reflected from the sample passes through to the photocell where the reflectance ratio is converted to a logarithmic density.[10]

The densitometer can measure portions of the visible spectrum by use of three wide band colored filters; blue, green and red. The amount of blue, green and red light detected is a function of the amount of each of the three process colored inks printed on paper. Yellow ink is measured using the blue filter, magenta ink is measured using the green filter and cyan ink is measured using the red filter. However, the densitometer does not have the same sensitvity to blue, green and red as the human eye, and therefore does not actually measure color with respect to how we see it. Even though it does not measure color exactly as the human eye sees it, a densitometer is a useful tool that is used to monitor and control the amount of each of the process colors on paper.[11]

In addition to the three colored filters used to measure three colored inks, there is a "visual" filter that is used when measuring the black ink. It is termed "visual" because it simulates human visual response. The eye's sensitivity to light varies from wavelength to wavelength across the visible spectrum. This sensitivity is low at 400 nanometers, gradually increases to maximum sensitivity at 550 nanometers, then decreases gradually to a low at 700 nanometers, as illustrated in Figure 7. Simply stated, the eye is more sensitive to the green band of light than to the blue and red bands.

When the visual filter is used to measure the black ink, it measures the relative intensity of light that is being transmitted by the ink and reflected by the paper with respect to how the human eye may perceive its luminance or lightness.

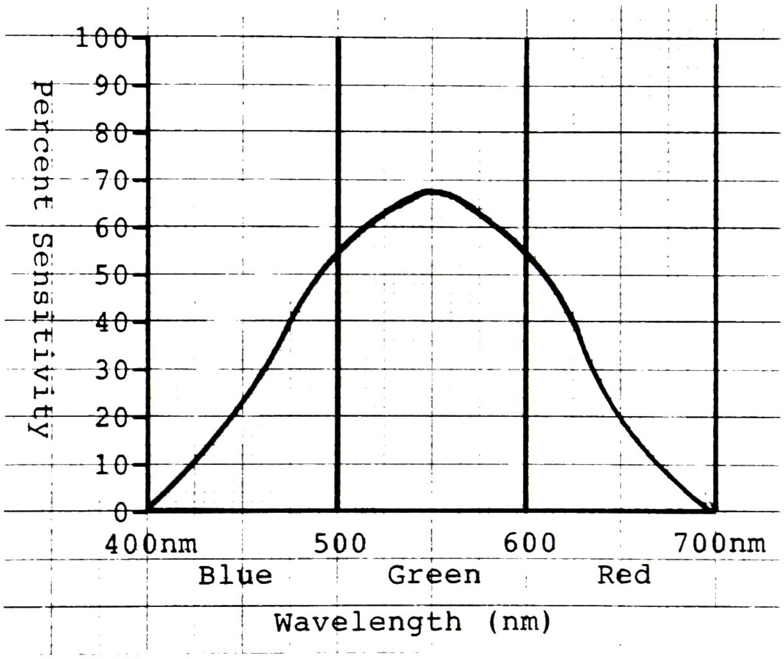


Figure 7 Curve showing luminosity function of the eye.

The visual filter is usually used to measure only the black ink because the black ink does not usually absorb more of one band than another, instead it absorbs all three bands equally (theoretically speaking). It is possible to use this filter to make measurements of the three process colored inks. Taking measurements of the three process colored inks through the visual filter would not indicate the particular hue of the color, but rather the relative luminance or lightness of that color with respect to how the human eye may perceive it (see appendix A).

Yule-Nielsen Equation

Given a unit area composed of colored dots as shown in Figure 8, where both the area covered by dots and the solid ink density of that color are given, the theoretical complimentary filter density of that unit area can be calculated by using an equation such as:

$$Dt = -\log[1-a(1-10^{-Ds})]$$

where: Dt = density of tint
Ds = density of solid
a = dot area of that unit area

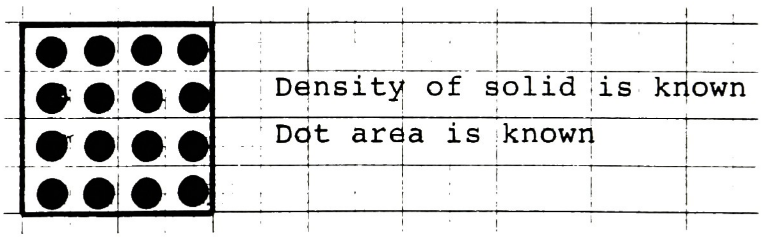


Figure 8. Unit area composed of dots of a single color.

By altering the equation in Figure 8, it is also possible to calculate the dot area coverage when given both the density of the tint and the solid ink density. In other words, if two of the three variables are known, then the third can be found. This equation is known as the Murray-Davies Equation (MDE) and simply plots density, or percent reflectance, against percent dot area. Plotting percent reflectance against percent dot area yields a curve such as the one illustrated in Figure 9. In theory, percent reflectance is a linear function of percent dot area, therefore a straight line curve results. In Figure 9, a ten percent dot area reflects 90% of the incident light, a 50% dot area reflects 50% of the incident light and a 90% dot area reflects ten percent of the incident light. Plotting density against percent dot area yields a different looking curve. This should be expected since density is a logarithmic function of reflectance. A typical curve

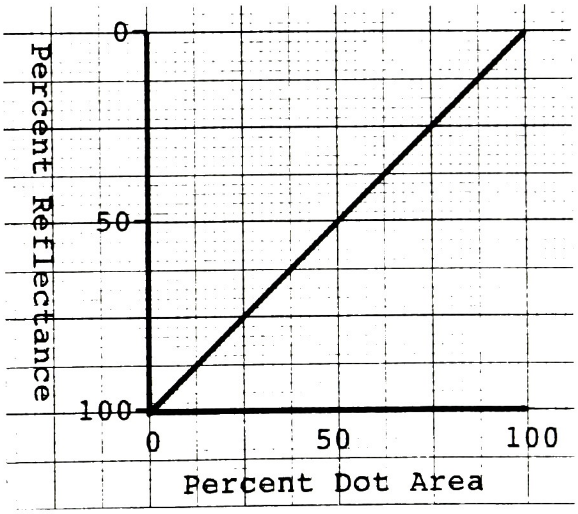


Figure 9. Curve plotting percent dot area against percent reflection of a halftone reproduction.

plotting density against percent dot area may look like the curve in Figure 10. In this figure, 100% dot area equals the density of the solid ink patch 1.30. The zero percent dot area equals the density of the paper (usually taken to be zero) and the curve in between is such that it starts

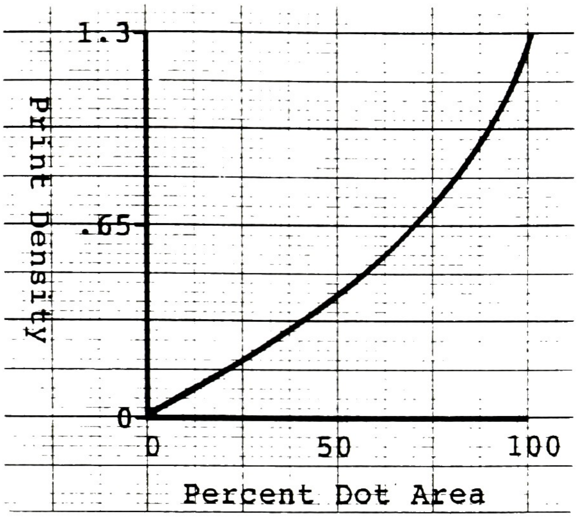
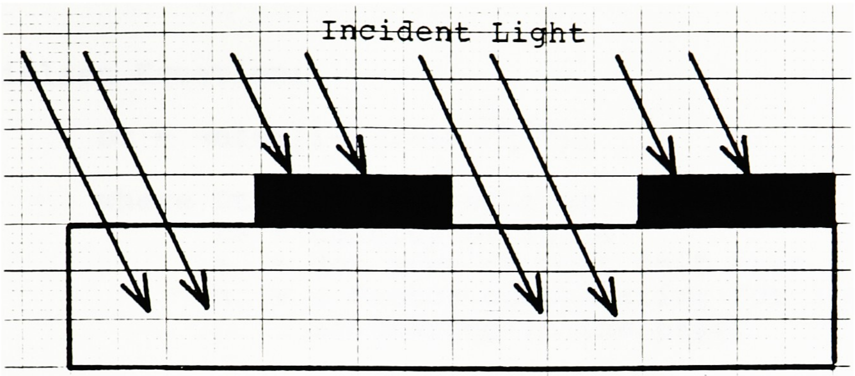


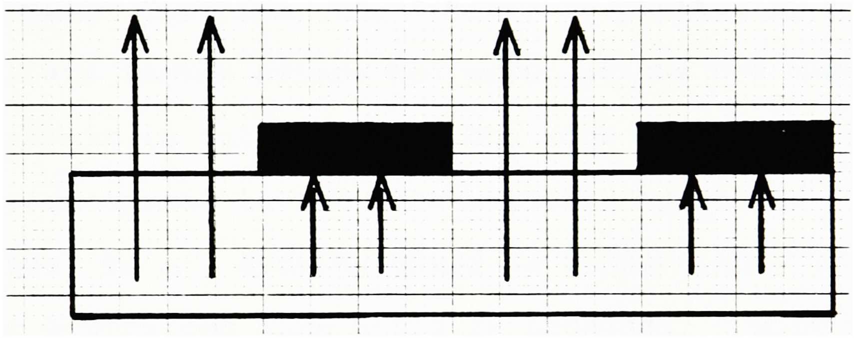
Figure 10. Curve plotting percent dot area against density of a halftone reproduction.

out with a low slope and gradually steepens as percent dot area increases.

In the Murray-Davies Equation, the penetration of light into the paper is neglected. This equation assumes that the light emerges from the paper exactly at the spot where it entered and this is not entirely true.[12] Light is scattered within the paper and some of the light is trapped below the dots and absorbed by the ink. Figure 11 illustrates how this trapping of light affects the percent reflectance of a unit area of a halftone reproduction. In Figure 11, the paper is covered with 50% dot area. However, instead of 50% reflectance due to 50% dot area, there is now only 25% reflectance.[13] In accordance, the density is increased from .3 to .6. Therefore, since the Murray-Davies Equation does not take this light scattering effect into consideration, the densities calculated from this equation



50% ink coverage
50% absorbed on entering paper



Half of remainder of light is absorbed on leaving the paper.

*Total Absorption = 75% of incident light
*Total Reflectance = 25% of incident light

Figure 11. The effect of internal light scattering within paper on the density of a halftone reproduction.

are usually lower than those measured on a densitometer.

To get a closer correspondance between calculated densities and measured ones, the Murray-Davies Equation must be altered to account for the light scattering effect. The Yule-Nielsen Equation (YNE) provides this necessary alteration by employing the "n" factor.[14] This "n" is a factor compensating for the effect of internal light scattering in the paper. The only difference between the

Yule-Nielsen Equation:

$$Dt = -n\log[1-a(1-10^{-Ds/n})]$$

where Dt = density of tint
Ds = density of solid
a = dot area of that unit area
n = n factor compensating for light scattering in the paper

and the older Murray-Davies Equation is that in the Yule-Nielsen Equation, the density is divided by an appropriate factor before the calculations are made, and the final result is multiplied by the same factor. When "n" = 1, it corresponds to the Murray-Davies Equation. If "n" were equal to ∞ , density would be proportional to dot area, so that a straight line would be obtained. Using various values for "n" and a solid ink density of 1.3, the relationship between density and percent dot area has been

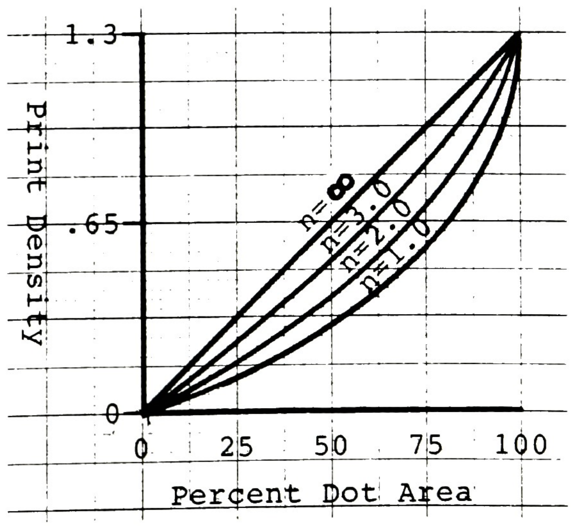


Figure 12. Curve plotting percent dot area against density of a halftone reproduction with different "n" values.

calculated using the Yule-Nielsen Equation and plotted in Figure 12. A low "n" value indicates that the trapping of light under the dots in the paper is small compared with dot size.[15]

The "n" factor is an arbitrary number and can be derived by measuring the densities of a unit area with a densitometer and then calculating the densities using the Murray-Davies Equation. The difference between the calculated densities and the measured densities will be due to the "n" factor. Further, the lower the "n" value the less light scattering taking place within the paper.

A value for "n" is mostly dependent upon the screen frequency and paper used. However, if these two variables are held constant, then a value for "n" can be determined based on ink coverage. Furthermore, if there is less ink on the paper (as in 100% GCR), then there is less chance that the light will be trapped by the ink. In turn, less light being trapped by the ink yields a lower "n" value and a closer lightness match to the original.

FOOTNOTES FOR CHAPTER TWO

[1]J.A.C. Yule, Principles of Color Reproduction, (New York: John Wiley & Sons, 1967), p.282.

[2]Ibid., p.282.

[3]Ibid., p.282.

[4]B. Philippsen, "The Effects On Hue Resulting From Black Overprinting In Halftone Reproductions," Masters Thesis, (Rochester Institute of Technology, May 1985), p.13.

[5]F.W. Clulow, Color Its Principles and Their Applications, (New York: Morgan and Morgan Inc. Publishers, 1972), p.87.

[6]Ibid., p.87.

[7]M.F. Southworth, "Achromatic Color: Programmed Color Removal," Quality Control Scanner, vol.4, no.7, p.4.

[8]J. Cogoli, Graphic Arts Photography: Black and White, (Pennsylvania: Graphic Arts Technical Foundation, 1981), p.73.

[9]Ibid., p.74.

[10]M.F. Southworth, "Densitometry," Quality Control Scanner, vol.1, no.2, p.1.

[11]Ibid., p.2.

[12]J.A.C. Yule, W.J. Nielsen, "The Penentration Of Light Into Paper and Its Effects On Halftone Reproductions," Technical Association of the Graphic Arts, (1951 TAGA Proceedings), p.65.

[13]Ibid., p.69.

[14]Ibid., p.72.

[15]Ibid., p.73.

CHAPTER THREE

HYPOTHESIS

For any given hue, the lightness of a two-color plus black reproduction system (such as 100% GCR) is a closer match to the original than the lightness obtained with a three-color reproduction system.

CHAPTER FOUR

LITERATURE REVIEW

Until recently few technical articles had been written about GCR. Most of the material that had been written is intended for the printing plant manager who usually knows very little about the GCR process. The articles usually talk about the advantages of GCR and how this "new" technique would be very profitable to the printer in the long run.

A paper dating back to 1948 with an article by Arthur C. Hardy and F.L. Wurzburg is probably the first to be published on GCR. They discuss how a set of equations produce a set of separations that look "unlike those to which the art is accustomed."[1] In a later paper by these same men, they state that "only with the use of electronics could such complex color correction calculations be performed with sufficient speed to make such a theory feasible."[2] It was not until just a few years ago that scanners were built with GCR capabilities.

Within the last three years, several technical papers have been written. Two 1984 TAGA papers, one by Dr. Abdel Ghaney Saleh and the other by Dr. Eggert Jung, discuss the

GCR theory.[3,4] Dr. Abdel Ghaney Saleh's paper gives an overview of the process and explains the effect of real inks on the process. His paper provides a much needed understanding of the GCR theory and process.

In 1985 more TAGA papers were written. Tony Johnson discusses the development of both UCR and GCR, and the history behind using black ink as a substitute for the gray component in a three color reproduction system. He also talks about the need for addition of the three color gray in the dark shadow areas of the reproduction.[5]

Michael Schwartz, Richard Holub and Jeffrey Gilbert, in their 1985 TAGA paper, try to summarize GCR and show how it takes place in neutrals and saturated colors.[6] They provide several graphs that show how yellow, magenta and cyan vary with black for a given neutral density.

The 1986 TAGA papers included five papers focussed on GCR. Mr. Gary Field presented an experiment involving color variability and its relationship to GCR reproductions versus conventional reproductions.[7] Another paper, by J.W. Birkenshaw, M. Scott - Taggart and K.T. Tritton, emphasizes the importance of the black printer in GCR reproductions. They discuss three types of black printers and how to determine a proper black printer for a given set of conditions.[8]

Perhaps the biggest contribution of written material on this subject comes from J.A.C. Yule in his book titled,

<u>Principles of Color Reproduction</u>.[9] In this book, he discusses light scattering and its effects on the density and lightness of hues. He talks about the "ideal black printer" and how it should be a record of the gray component of the original.

Another paper that contributes a great deal to this thesis is Yule and Nielsen's 1951 TAGA paper "The Penetration Of Light Into Paper And Its Effects On Halftone Reproduction."[10] In this paper, they discuss how the old Murray-Davies Equation did not take into account the light scattering effect. They explain how a value could be placed in the equation that would account for the light scattering. The equation is known as the Yule-Nielsen Equation and the value is often referred to as the "n" value.

FOOTNOTES FOR CHAPTER FOUR

[1]A.C. Hardy, F.L. Wurzburg Jr., "Color Correction in Color Printing," Journal of the Optical Society of America, vol.38, no.4, (April, 1948), p.300.

[2]A.C. Hardy, F.L. Wurzburg Jr., "An Electronic Mehtod for Solving Simultaneous Equations," Journal of the Optical Society of America, vol.38, no.4, (April 1948), p.308.

[3]Dr. Abdel Ghany Saleh, "Investigation into the Application of Achromatic Synthesis to the Printing Industry," Technical Association of the Graphic Arts, (1984 TAGA Proceedings), p.157.

[4]Dr. Eggert Jung, "Programmed and Complementary Color Reduction," Technical Association of the Graphic Arts, (1984 TAGA Proceedings), p.136.

[5]T. Johnson, "Polychromatic Colour Removal - Revolution or Evolution," Technical Association of the Graphic Arts, (1985 TAGA Proceedings), p.1.

[6]M. Schwartz, R. Holub, J. Gilbert, "Measurements of Gray Component Reduction in Neutrals and Saturated Colors," Technical Association of the Graphic Arts, (1985 TAGA Proceedings), p.17.

[7]G. Field, "Color Variability Associated with Printing GCR and Color Separations," Technical Association of the Graphic Arts, (1986 TAGA Proceedings), p.145.

[8]J.W. Birkenshaw, M. Scott - Taggart, K.T. Tritton, "The Black Printer," Technical Association of the Graphic Arts, (1986 TAGA Proceedings), p.403.

[9]J.A.C. Yule, Principles of Color Reproduction, (New York: John Wiley & Sons, 1967).

[10]J.A.C. Yule, W.I. Nielsen, "The Penetration of Light Into Paper and Its Effect on Halftone Reproduction, Technical Association of the Graphic Arts, (1951 TAGA Proceedings), p.65.

CHAPTER FIVE

METHODOLOGY

A layout is prepared to accomodate 12 one-inch square screen tint configurations. A color bar is included to provide the necessary solid ink densities. All screen tints are 65-line, square dot and angled at 45 degrees. They are generated on an electronic dot generating scanner to ensure hard dots.

The 12 tint configurations can be identified as follows: A^1 - F^1 are dot configurations representing six different hues using only the three transparent process colors yellow, magenta and cyan (three-color reproduction system). A^2 - F^2 are the corresponding hues with black replacing the graying component (two-color plus black reproduction system, such as 100% GCR). The GCR transformations are done implementing the electronic dot generating scanner's GCR function at 100% utilization.

A^1	11% yellow 19% magenta 31% cyan	A^2	13% black 13% magenta 31% cyan
B^1	19% yellow 31% magenta 41% cyan	B^2	23% black 19% magenta 41% cyan

C^1 19% yellow
11% magenta
31% cyan

D^1 31% yellow
19% magenta
41% cyan

E^1 19% yellow
31% magenta
11% cyan

F^1 31% yellow
41% magenta
19% cyan

C^2 19% yellow
10% black
31% cyan

D^2 28% yellow
23% black
41% cyan

E^2 19% yellow
31% magenta
10% black

F^2 31% yellow
41% magenta
19% black

Screens are generated on the scanner and stripped in such a way to minimize dot overlap. It has been determined by Brian Philippsen in his 1985 Thesis that hue shifts occur when the black dot overlaps transparent inks.[1] Therefore in this experiment, the black is stripped so that it does not overlap any of the transparent inks. Further, the assumption is made that there is no overlap of any of the dots in any tint configuration in this experiment.

A negative matchprint is made of the 12 tint configurations. Transmission densitometric readings through the four filters are taken of this negative matchprint before it is laminated to its base material. This unlaminated negative matchprint serves as the original in this experiment. The matchprint is then laminated to its base material and reflective densitometric readings are taken through the four filters.

Based on densitometric readings of the unlaminated and laminated negative matchprint, values for "n" are calculated for each of the 12 tint configurations using the Yule Nielsen Equation.

All "n" values in this experiment are based on visual filter readings. Blue, green and red filter readings are made so that an average reflectance curve may be graphed for each tint configuration.

It has been determined by Yule and Nielsen in their 1951 TAGA paper that the "n" value is lowest for coated papers and coarse screens.[2] Since in this experiment the paper and screens used will be the same for all 12 tint configurations, they will affect all 12 tint configurations the same.

FOOTNOTES FOR CHAPTER FIVE

[1]B. Philippsen, "The Effects On Hue Resulting From Black Overprinting In Halftone Reproductions." Masters Thesis, (Rochester Institute of Technology, May 1985), p.57.

[2]J.A.C. Yule, W. J. Nielsen, "The Penetration Of Light Into Paper And Its Effects On Halftone Reproduction," Technical Association of the Graphic Arts, (1951 TAGA Proceedings), p.65.

CHAPTER SIX

DATA COLLECTION

The analysis used in this experiment is designed to compare the light scattering effect which takes place in a three-color reproduction system versus that in a two-color plus black reproduction system (such as 100% GCR). "N" values will be derived and used to determine the degree of light scattering taking place.

The solid ink densities are listed in Tables 1 and 2. The average reflectance curves for these solid ink densities are presented in Figures 13-16.

The 12 tint cofigurations are analyzed on a reflection densitometer. In each configuration, nine readings through each of the four filters are taken and averages determined. An average reflectance curve for each of the 12 tint configurtions is plotted. The numerical data is listed in Tables 3-14 and the average reflectance curves are presented in Figures 17-28.

Nine transmission visual filter readings are taken of each configuration in the original matchprint and divided by nine. This data is listed in Tables 15-17. After the matchprint is laminated to the base material, the visual filter readings are repeated. This data is listed in Tables 18-20.

Values for "n" are determined using the Yule-Nielsen Equation and are listed in Table 21. A graph plotting "n" value against tint configuration is presented in Figure 29.

The paper factor

Visual	Blue	Green	Red
.15	.20	.17	.14

is subtracted from all reflection densities. Similarly, the film factor

Visual	Blue	Green	Red
.04	.03	.05	.07

is subtracted from all transmission densities.

Values for "n" based on blue, green and red filter readings are also determined and listed in Appendix B. They will not however, be used in this experiment.

Table 1.

Density and corresponding reflectance value for each broad band.
Sample: Solid yellow (Y) and solid magenta (M).

	BLUE BAND		GREEN BAND		RED BAND	
Sample:	Y	M	Y	M	Y	M
Density:	.96	.71	.06	1.31	.01	.21
Reflectance:	11	20	87	5	98	62

Table 2.

Density and corresponding reflectance value for each broad band.
Sample: Solid cyan (C) and solid black (K).

	BLUE BAND		GREEN BAND		RED BAND	
Sample:	C	K	C	K	C	K
Density:	.08	1.51	.32	1.51	1.12	1.60
Reflectance:	83	3	48	3	8	3

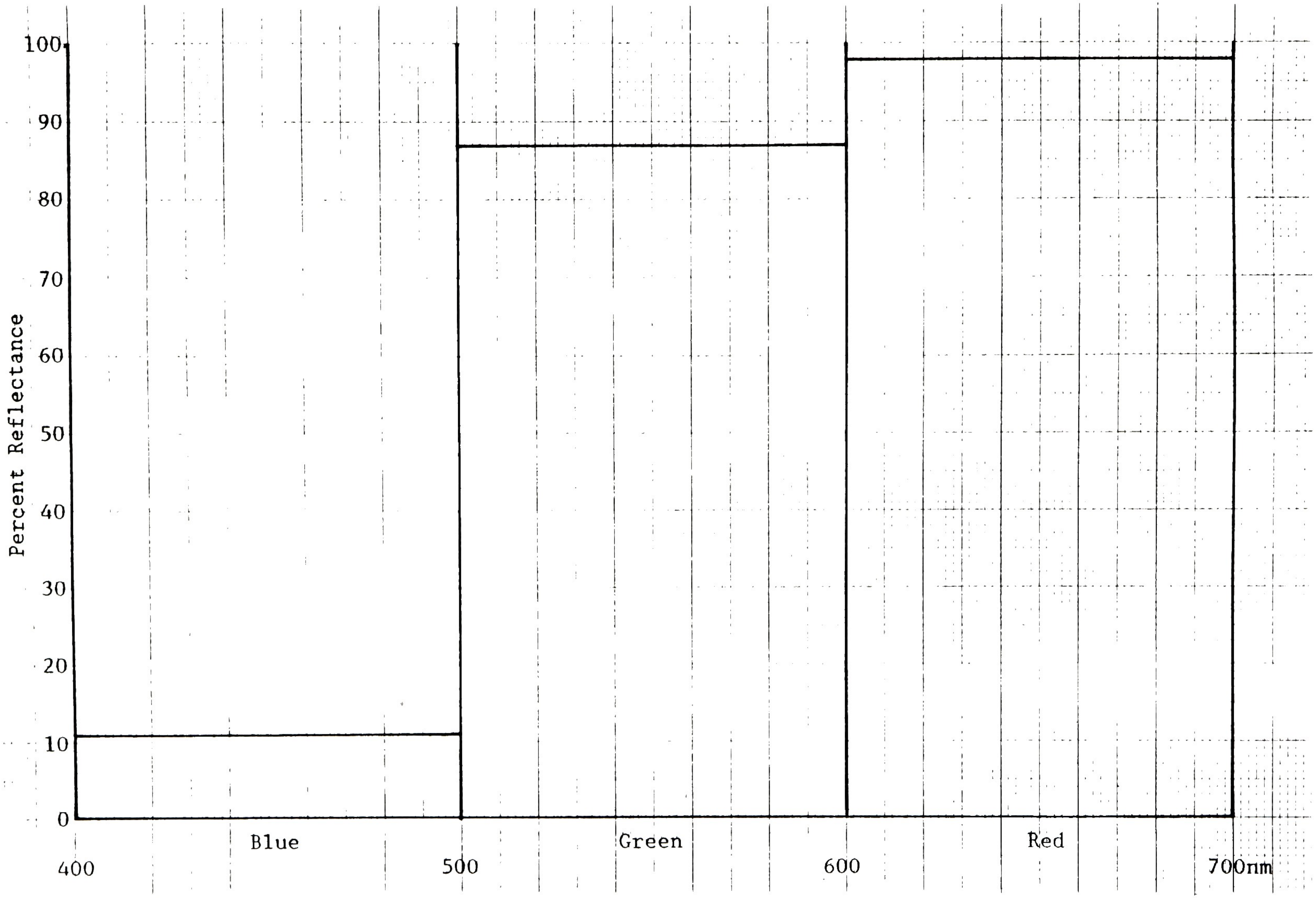


Figure 13. Average reflectance curve for solid yellow.

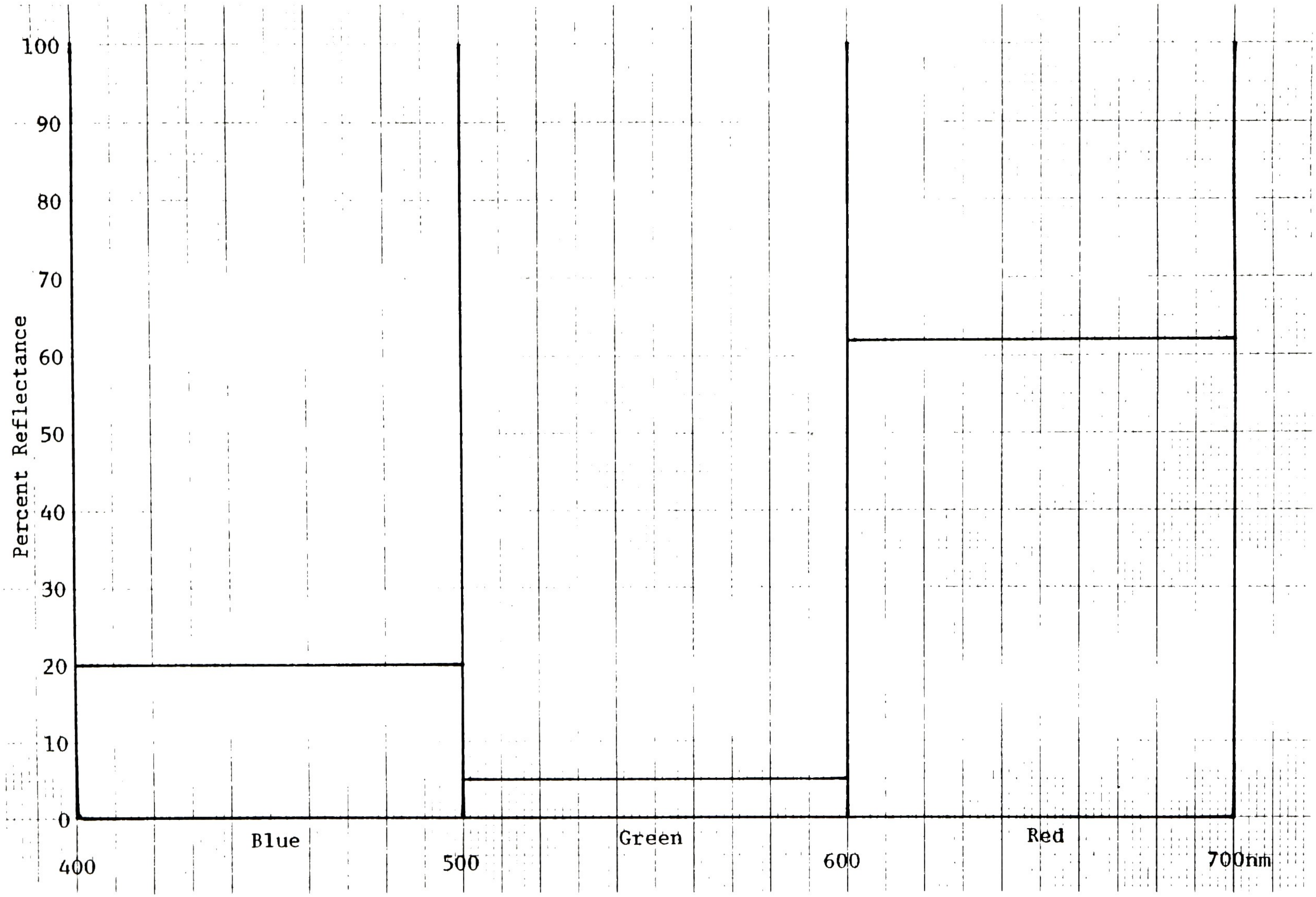


Figure 14. Average reflectance curve for solid magenta.

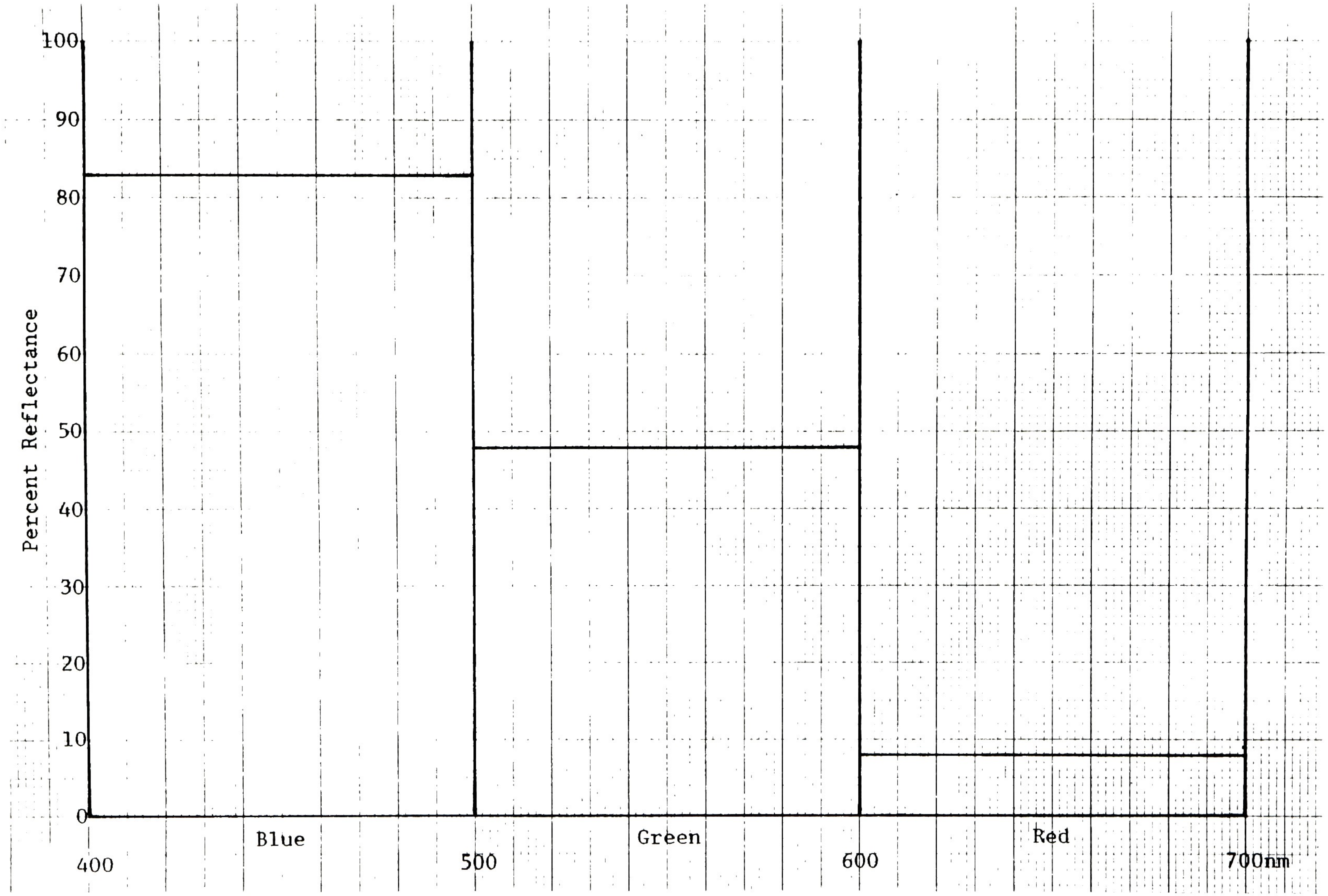


Figure 15. Average reflectance curve for solid cyan.

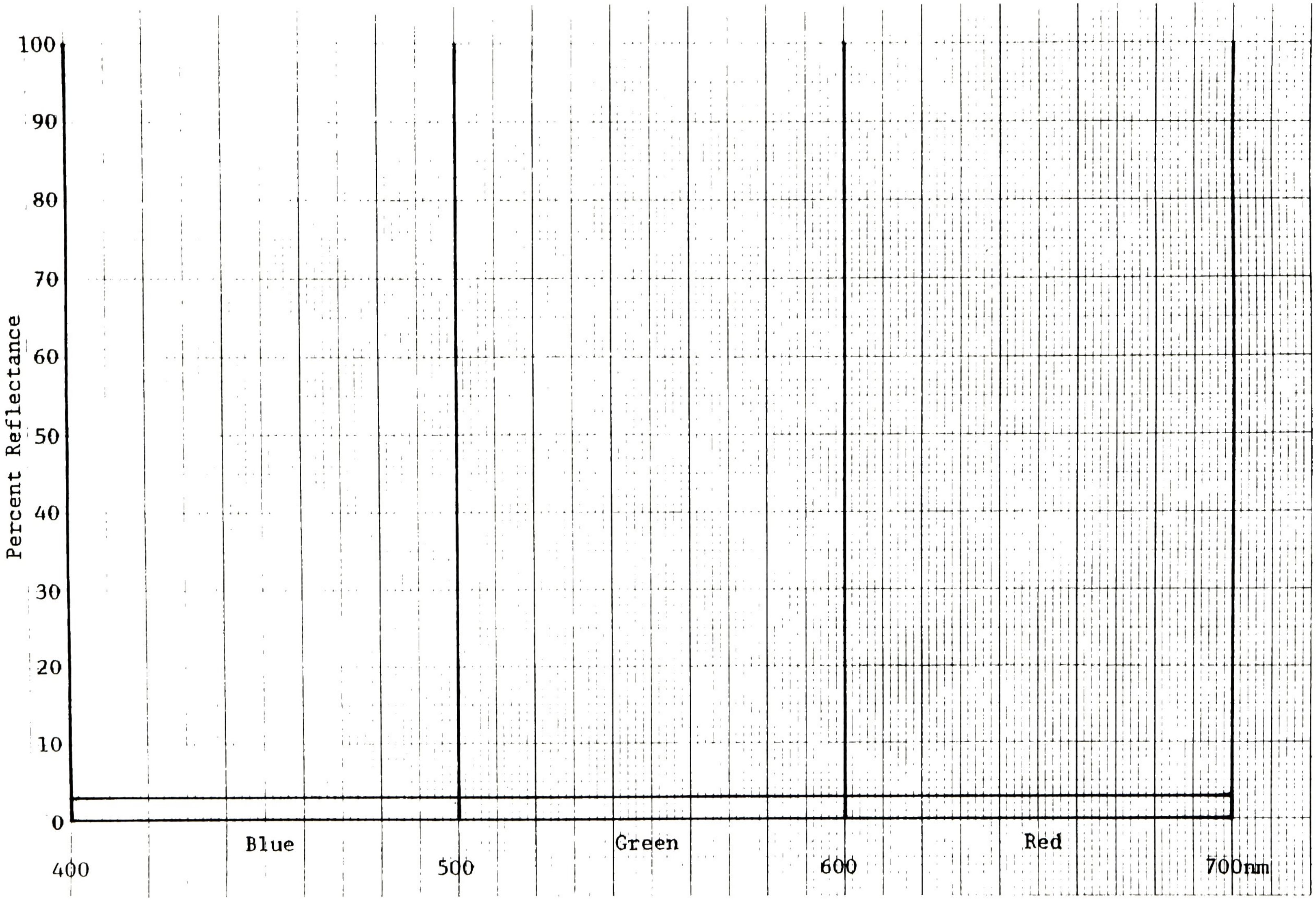


Figure 16. Average reflectance curve for solid black.

Table 3.

Average density based on nine samplings and corresponding reflectance value for each broad band.
Tint Configuration: A^1 Three-Color Reproduction System.

	BLUE BAND	GREEN BAND	RED BAND
Tint:	A^1	A^1	A^1
	.45	.49	.46
	.46	.49	.45
	.45	.49	.46
	.46	.49	.45
	.45	.48	.45
	.45	.48	.45
	.45	.49	.45
	.45	.48	.45
	.46	.49	.46
Total:	4.09	4.38	4.08
	÷ 9	÷ 9	÷ 9
	.45	.49	.45
-Paper:	-.20	-.17	-.14
Average:	.25	.32	.31
Reflectance:	56	48	49

Table 4.

Average density based on nine samplings and corresponding reflectance value for each broad band.
Tint Configuration: A^2 Two-Color Plus Black Reproduction System.

	BLUE BAND	GREEN BAND	RED BAND
Tint:	A^2	A^2	A^2
	.47	.58	.61
	.46	.58	.61
	.47	.59	.62
	.47	.58	.61
	.47	.58	.62
	.47	.59	.62
	.46	.57	.61
	.46	.57	.61
	.47	.59	.62
Total:	4.20	5.23	5.53
	÷ 9	÷ 9	÷ 9
	.47	.58	.61
-Paper:	-.20	-.17	-.14
Average:	.27	.41	.47
Reflectance:	54	39	34

Table 5.

Average density based on nine samplings and corresponding reflectance value for each broad band.
Tint Configuration: B^1 Three-Color Reproduction System.

	BLUE BAND	GREEN BAND	RED BAND
Tint:	B^1	B^1	B^1
	.61	.62	.57
	.60	.61	.57
	.60	.61	.57
	.61	.62	.57
	.61	.62	.57
	.60	.61	.57
	.60	.62	.57
	.60	.61	.57
	.61	.62	.57
Total:	5.44	5.54	5.13
	÷ 9	÷ 9	÷ 9
	.60	.62	.57
-Paper:	-.20	-.17	-.14
Average:	.40	.45	.43
Reflectance:	40	35	37

Table 6.

Average density based on nine samplings and corresponding reflectance value for each broad band.
Tint Configuration: B^2 Two-Color Plus Black Reproduction System.

	BLUE BAND	GREEN BAND	RED BAND
Tint:	B^2	B^2	B^2
	.63	.79	.89
	.61	.78	.91
	.60	.78	.92
	.61	.77	.87
	.60	.77	.89
	.61	.78	.90
	.61	.78	.86
	.61	.77	.88
	.60	.77	.89
Total:	5.48	6.99	8.01
	÷ 9	÷ 9	÷ 9
	.61	.78	.89
-Paper:	-.20	-.17	-.14
Average:	.41	.61	.75
Reflectance	39	25	18

Table 7.

Average density based on nine samplings and corresponding reflectance value for each broad band.
Tint Configuration: C^1 Three-Color Reproduction System.

	BLUE BAND	GREEN BAND	RED BAND
Tint:	C^1	C^1	C^1
	.47	.41	.44
	.47	.41	.43
	.47	.41	.44
	.48	.41	.44
	.48	.41	.43
	.48	.41	.43
	.47	.41	.43
	.47	.41	.43
	.47	.41	.44
Total:	4.26	3.69	3.91
	÷ 9	÷ 9	÷ 9
	.47	.41	.43
-Paper	-.20	-.17	-.14
Average:	.27	.24	.29
Reflectance:	54	58	51

Table 8.

Average density based on nine samplings and corresponding reflectance value for each broad band.
Tint Configuration: C^2 Two-Color Plus Black Reproduction System.

	BLUE BAND	GREEN BAND	RED BAND
Tint:	C^2	C^2	C^2
	.48	.41	.56
	.48	.40	.55
	.48	.40	.55
	.48	.40	.56
	.48	.41	.56
	.48	.41	.55
	.48	.41	.56
	.48	.41	.55
	.47	.41	.56
Total:	4.31	3.66	5.00
	÷ 9	÷ 9	÷ 9
	.48	.41	.56
-Paper:	-.20	-.17	-.14
Average:	.28	.24	.42
Reflectanc:	52	58	38

Table 9.

Average density based on nine samplings and corresponding reflectance value for each broad band.
Tint Configuration: D^1 Three-Color Reproduction System.

	BLUE BAND	GREEN BAND	RED BAND
Tint:	D^1	D^1	D^1
	.62	.53	.54
	.62	.53	.55
	.61	.53	.55
	.61	.52	.55
	.61	.52	.55
	.62	.53	.55
	.62	.53	.55
	.62	.53	.55
	.62	.53	.55
Total:	5.55	4.75	4.94
	÷ 9	÷ 9	÷ 9
	.62	.53	.55
-Paper:	-.20	-.17	-.14
Average:	.42	.36	.41
Reflectance:	38	44	39

Table 10.

Average density based on nine samplings and corresponding reflectance value for each broad band.
Tint Configuration: D^2 Two-Color Plus Black Reproduction System.

	BLUE BAND	GREEN BAND	RED BAND
Tint:	D^2	D^2	D^2
	.75	.59	.83
	.75	.59	.84
	.75	.60	.85
	.75	.59	.84
	.75	.59	.85
	.75	.59	.85
	.75	.60	.85
	.75	.60	.86
	.75	.60	.86
Total:	6.75	5.35	7.63
	÷ 9	÷ 9	÷ 9
	.75	.59	.85
-Paper:	-.20	-.17	-.14
Average:	.55	.42	.71
Reflectance:	28	38	20

Table 11.

Average density based on nine samplings and corresponding reflectance value for each broad band.
Tint Configuration: E^1 Three-Color Reproduction System.

	BLUE BAND	GREEN BAND	RED BAND
Tint:	E^1	E^1	E^1
	.59	.53	.33
	.58	.52	.32
	.57	.52	.32
	.57	.52	.32
	.57	.52	.32
	.58	.52	.32
	.57	.52	.33
	.58	.52	.32
	.58	.52	.33
Total:	5.19	4.69	2.91
	÷ 9	÷ 9	÷ 9
	.58	.52	.32
-Paper	-.20	-.17	-.14
Average:	.38	.35	.18
Reflectance:	42	45	66

Table 12.

Average density based on nine samplings and corresponding reflectance value for each broad band.
Tint Configuration: E^2 Two-Color Plus Black Reproduction System.

	BLUE BAND	GREEN BAND	RED BAND
Tint:	E^2	E^2	E^2
	.69	.62	.34
	.71	.63	.34
	.71	.63	.34
	.68	.62	.34
	.69	.62	.34
	.70	.63	.34
	.67	.61	.34
	.69	.62	.34
	.70	.62	.34
Total:	6.24	5.60	3.04
	÷ 9	÷ 9	÷ 9
	.69	.62	.34
-Paper:	-.20	-.17	-.14
Average:	.49	.45	.20
Reflectance:	32	35	63

Table 13.

Average density based on nine samplings and corresponding reflectance value for each broad band.
Tint Configuration: F^1 Three-Color Reproduction System.

	BLUE BAND	GREEN BAND	RED BAND
Tint:	F^1	F^1	F^1
	.76	.65	.41
	.76	.65	.40
	.75	.65	.41
	.76	.64	.40
	.76	.65	.41
	.76	.65	.41
	.76	.65	.41
	.77	.66	.41
	.76	.65	.41
Total:	6.84	5.85	3.67
	÷ 9	÷ 9	÷ 9
	.76	.65	.41
-Paper	-.20	-.17	-.14
Average:	.56	.48	.27
Reflectance:	28	33	54

Table 14.

Average density based on nine samplings and corresponding reflectance value for each broad band.
Tint Configuration: F^2 Two-Color Plus Black Reproduction System.

	BLUE BAND	GREEN BAND	RED BAND
Tint:	F^2	F^2	F^2
	.94	.90	.46
	.93	.91	.46
	.93	.91	.46
	.95	.91	.46
	.94	.91	.46
	.93	.91	.46
	.95	.91	.46
	.94	.91	.46
	.93	.91	.46
Total:	8.44	8.18	4.14
	÷ 9	÷ 9	÷ 9
	.94	.91	.46
-Paper:	-.20	-.17	-.14
Average:	.74	.74	.32
Reflectance:	18	18	48

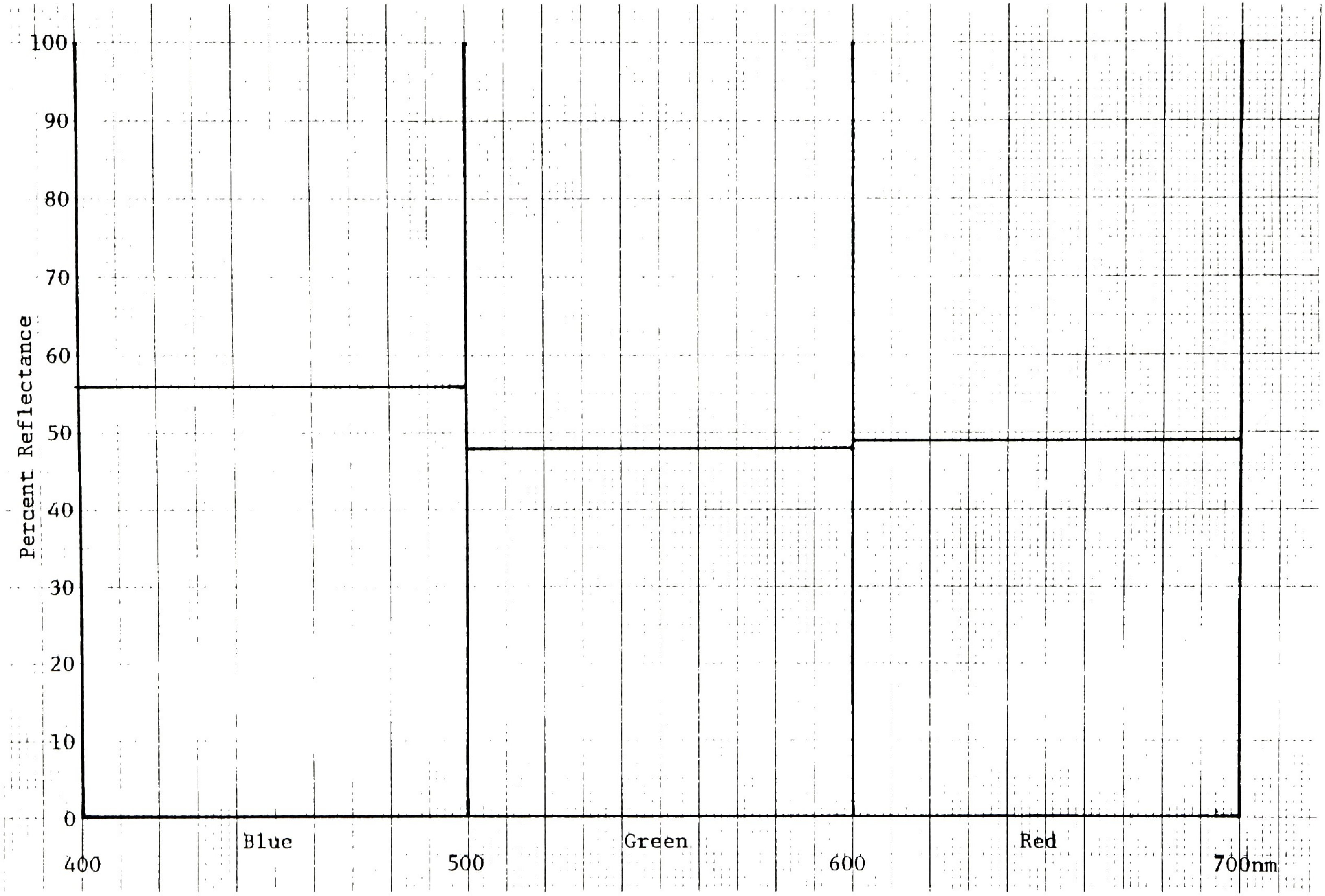


Figure 17. Average reflectance curve for Tint Configuration A[1].

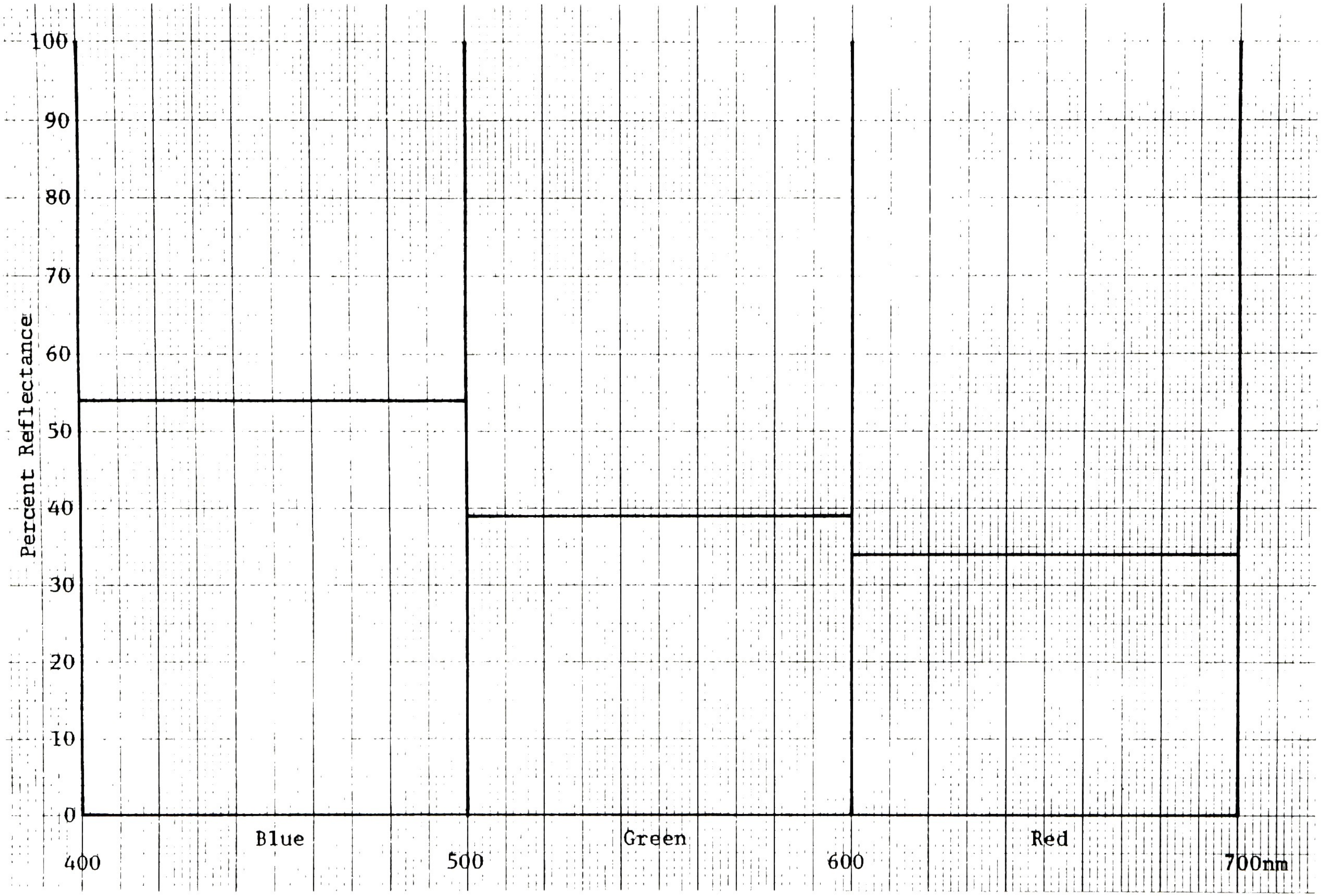


Figure 18. Average reflectance curve for Tint Configuration A^2.

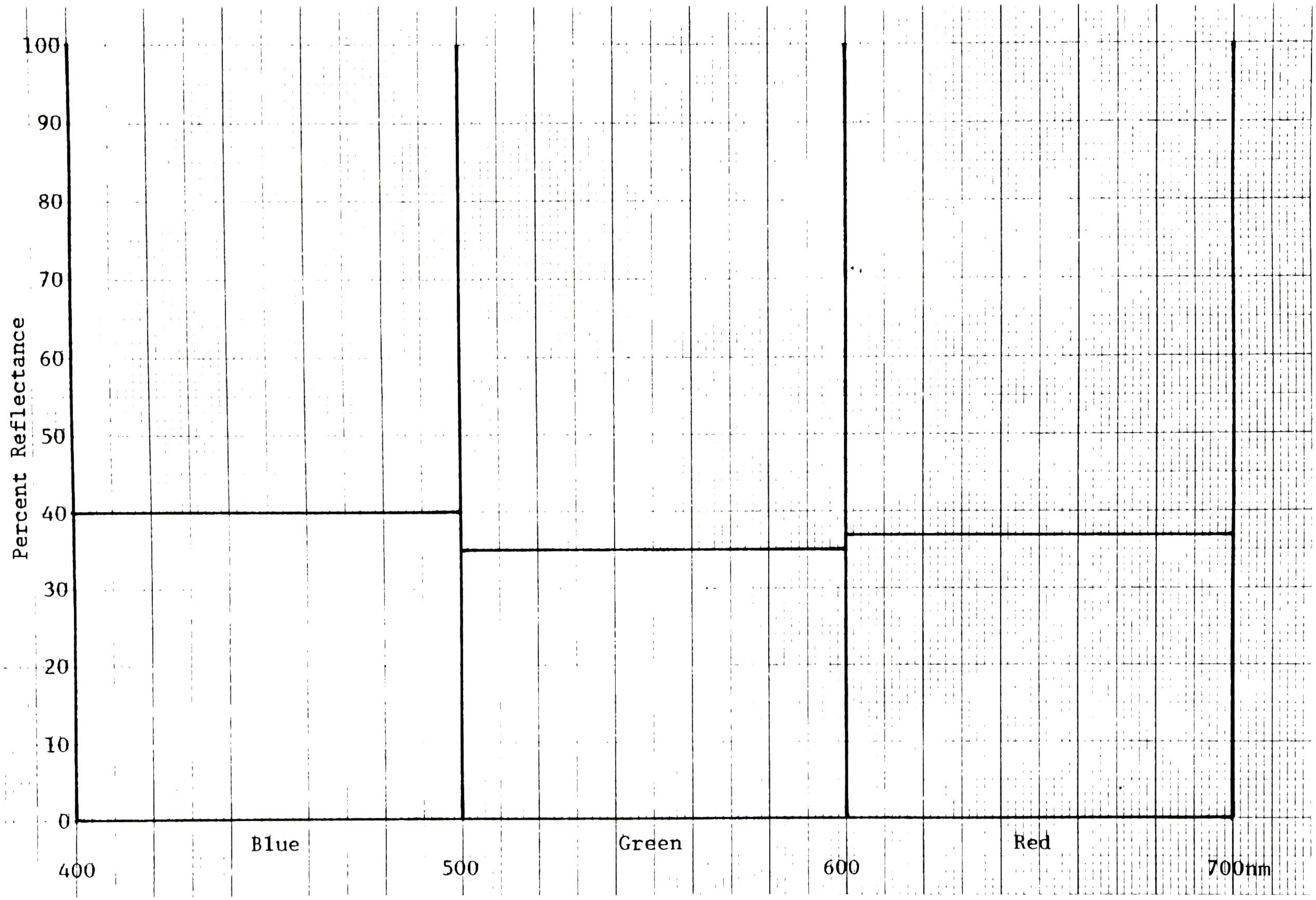


Figure 19. Average reflectance curve for Tint Configuration B[1].

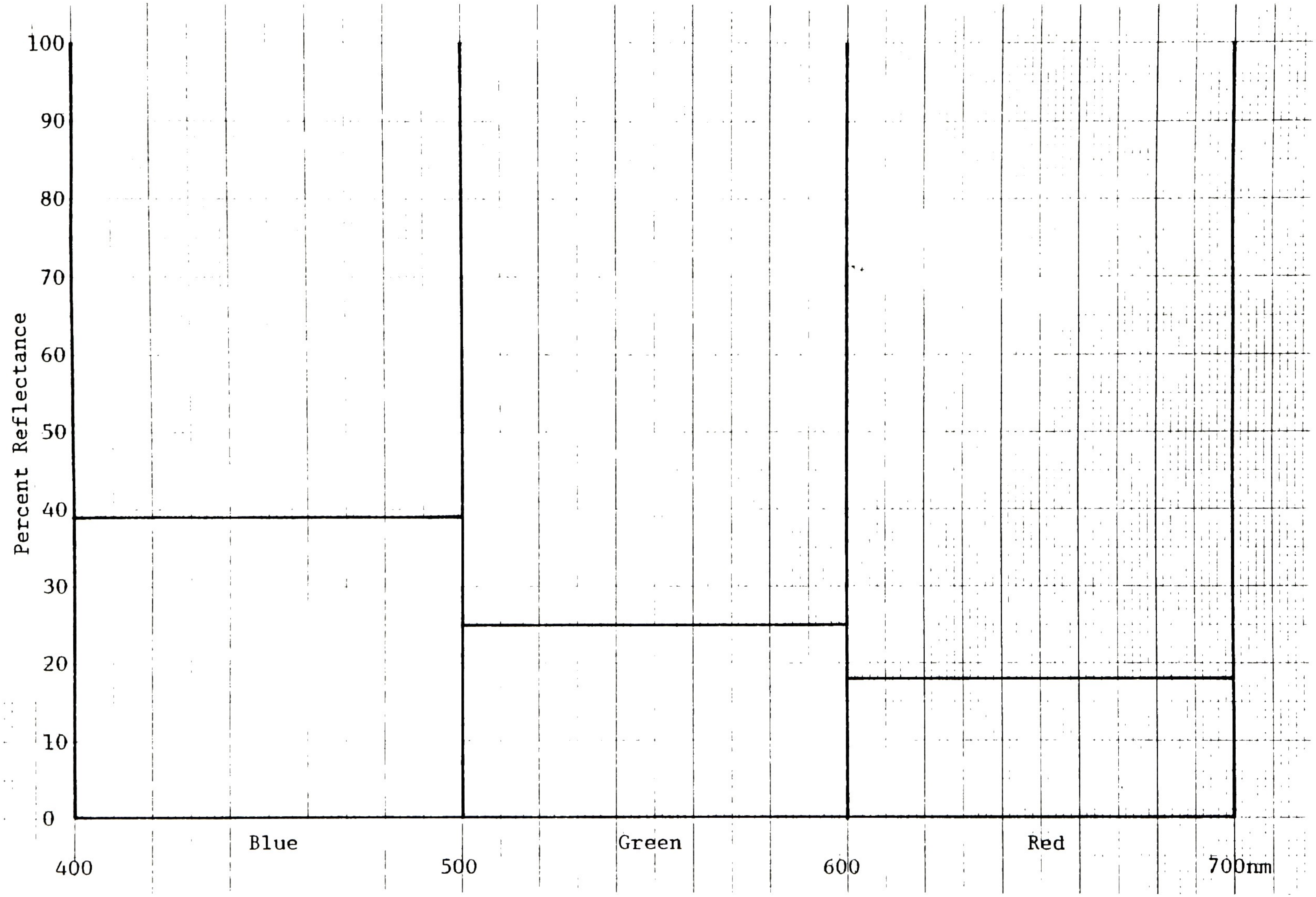


Figure 20. Average reflectance curve for Tint Configuration B2.

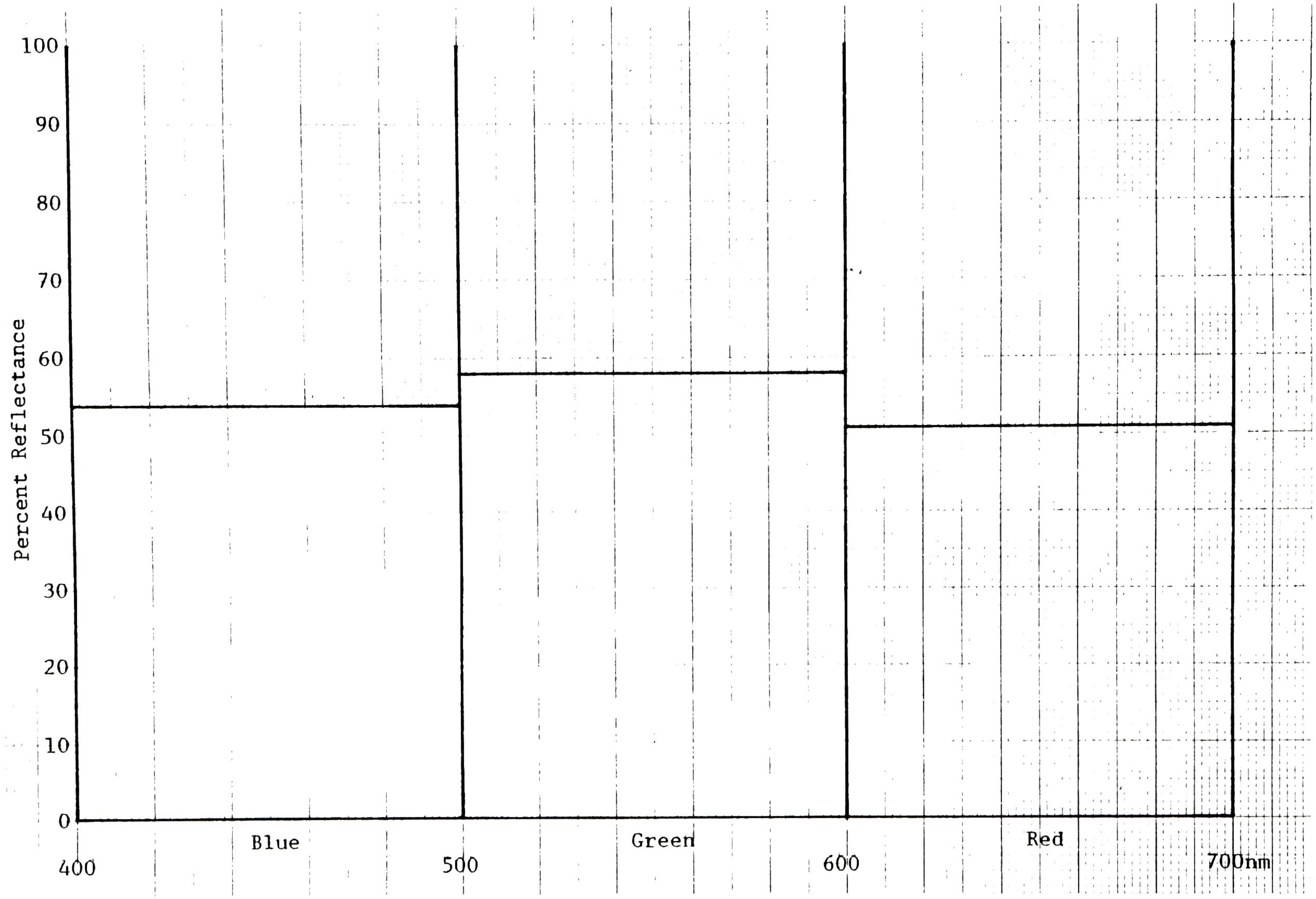


Figure 21. Average reflectance curve for Tint Configuration C^1.

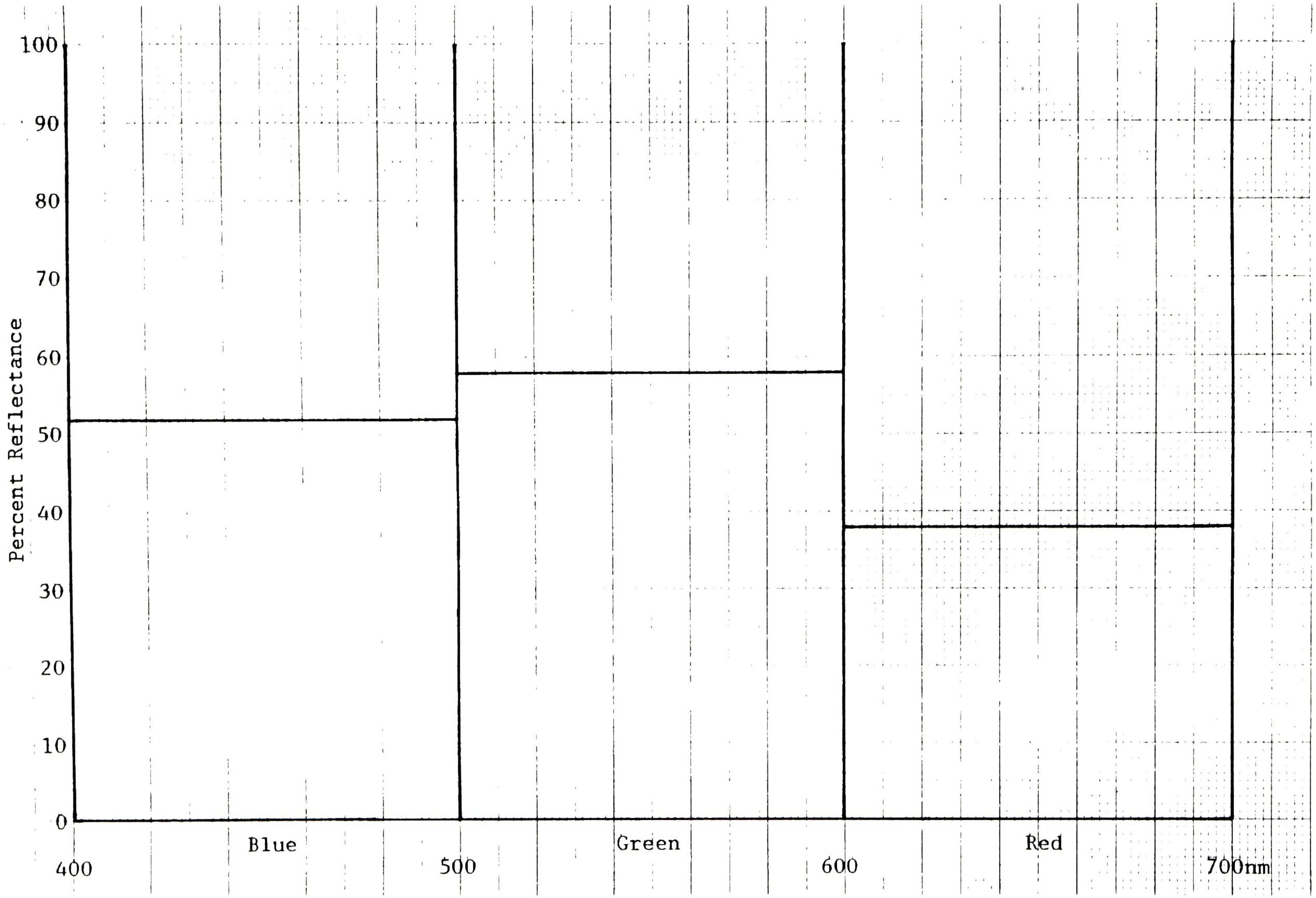


Figure 22. Average reflectance curve for Tint Configuration C^2.

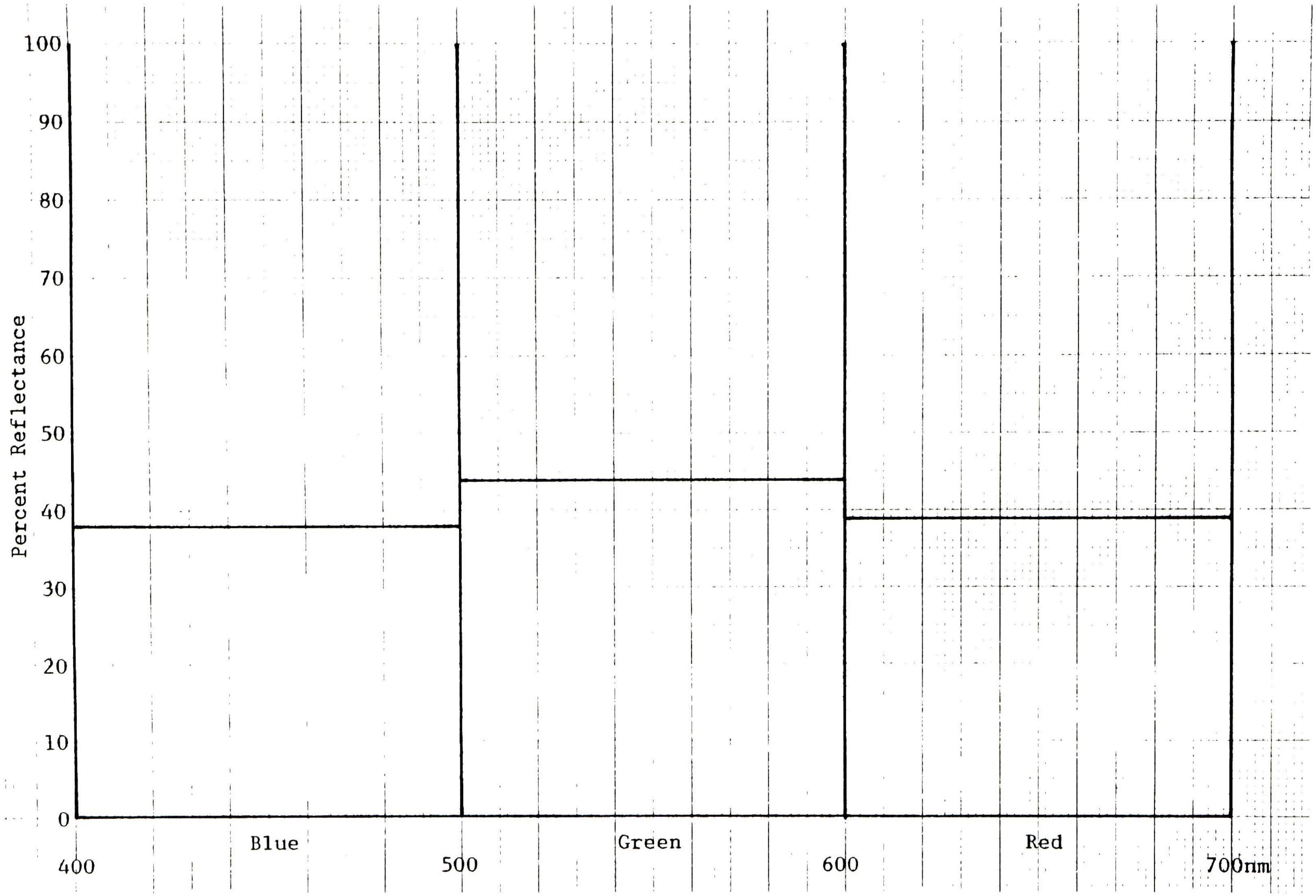


Figure 23. Average reflectance curve for Tint Configuration D[1].

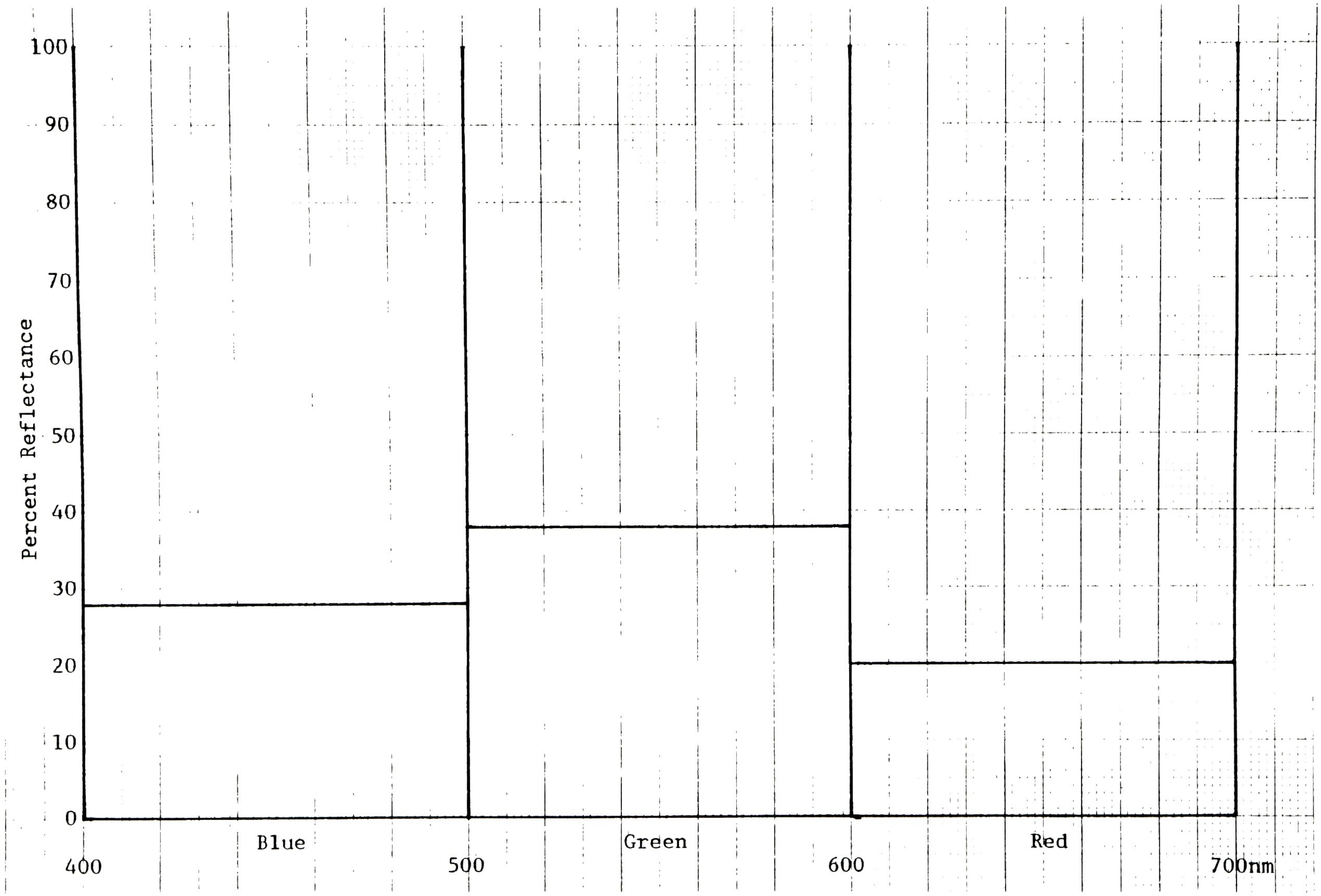


Figure 24. Average reflectance curve for Tint Configuration D^2.

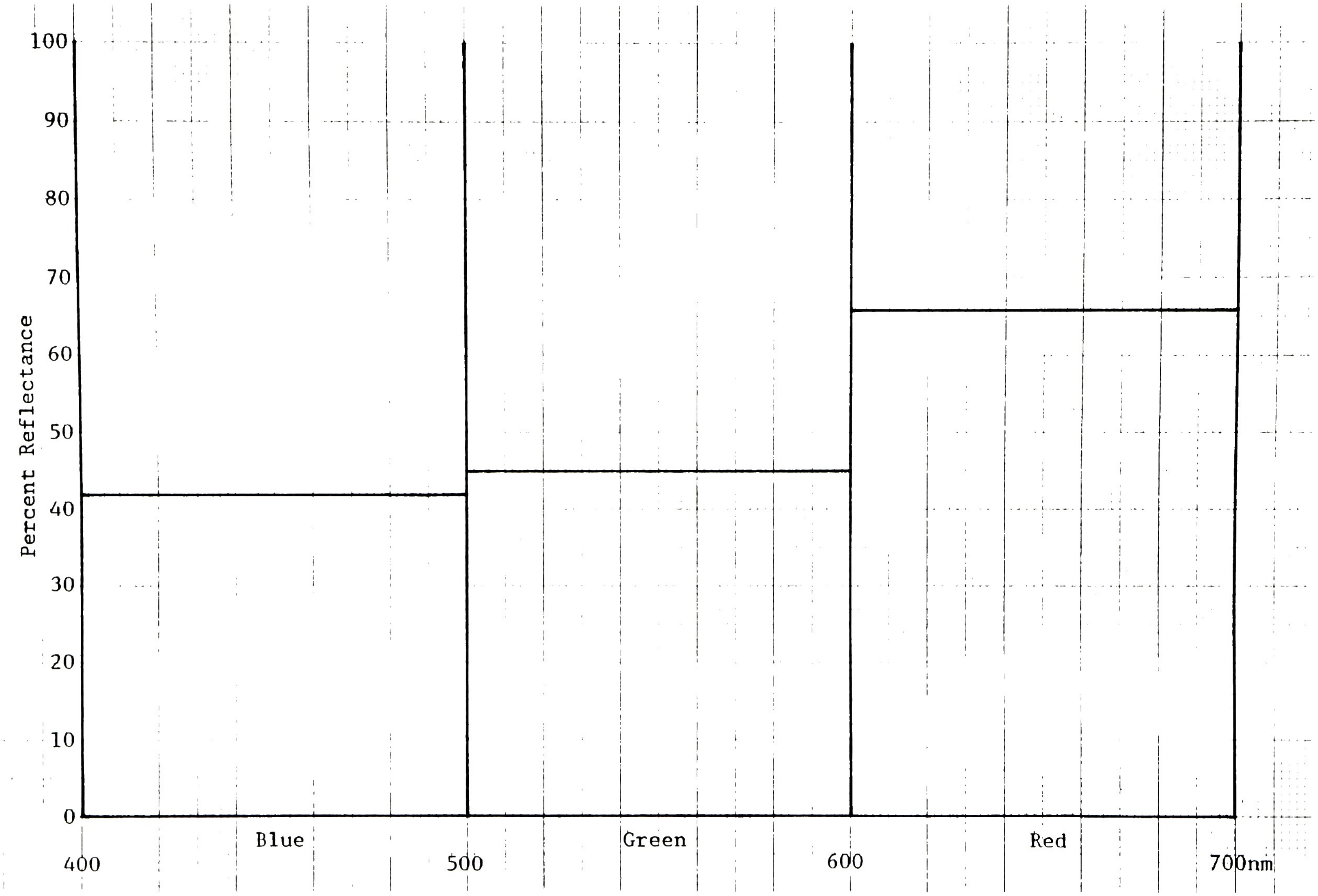


Figure 25. Average reflectance curve for Tint Configuration E[1].

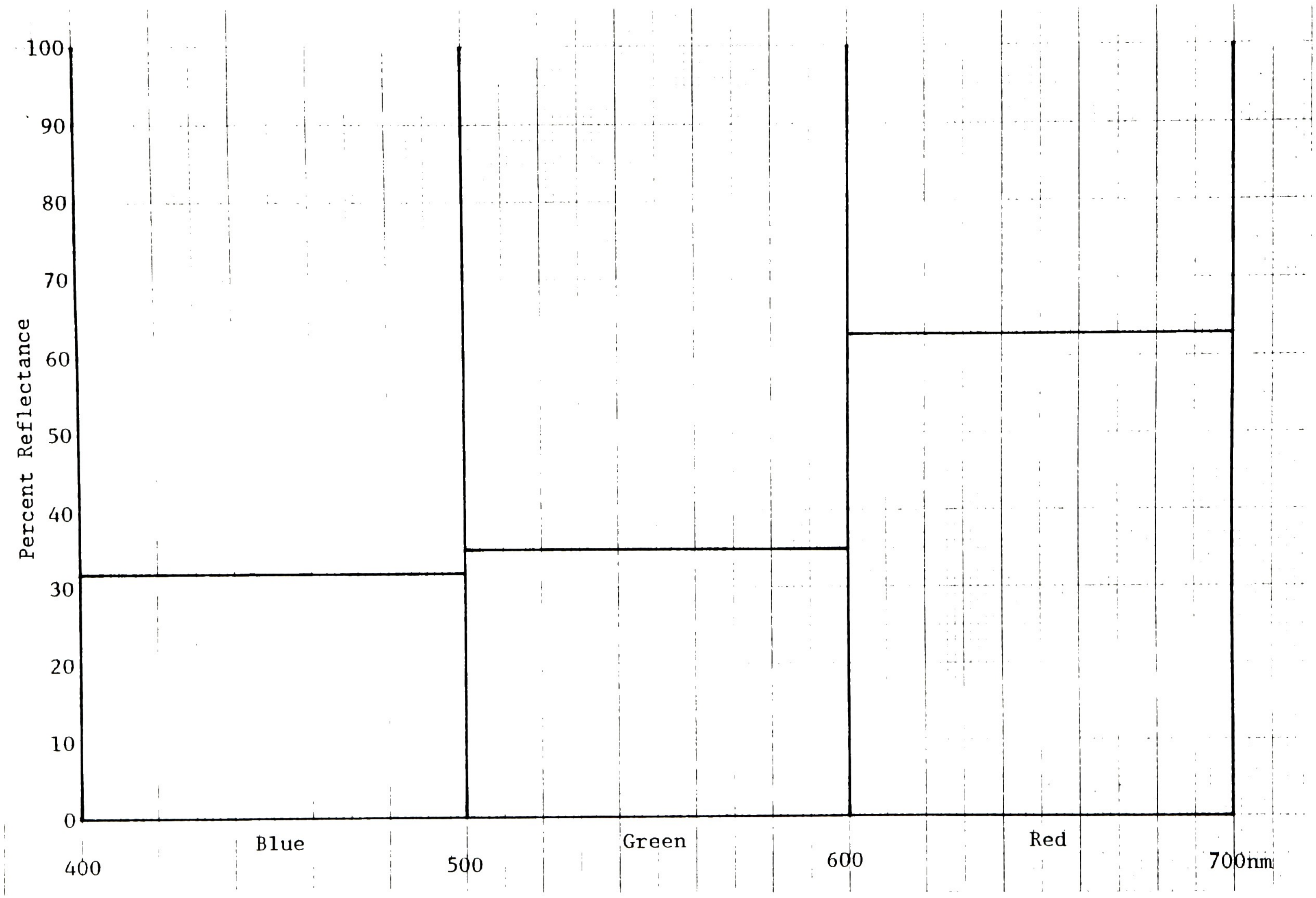


Figure 26. Average reflectance curve for Tint Configuration E^2.

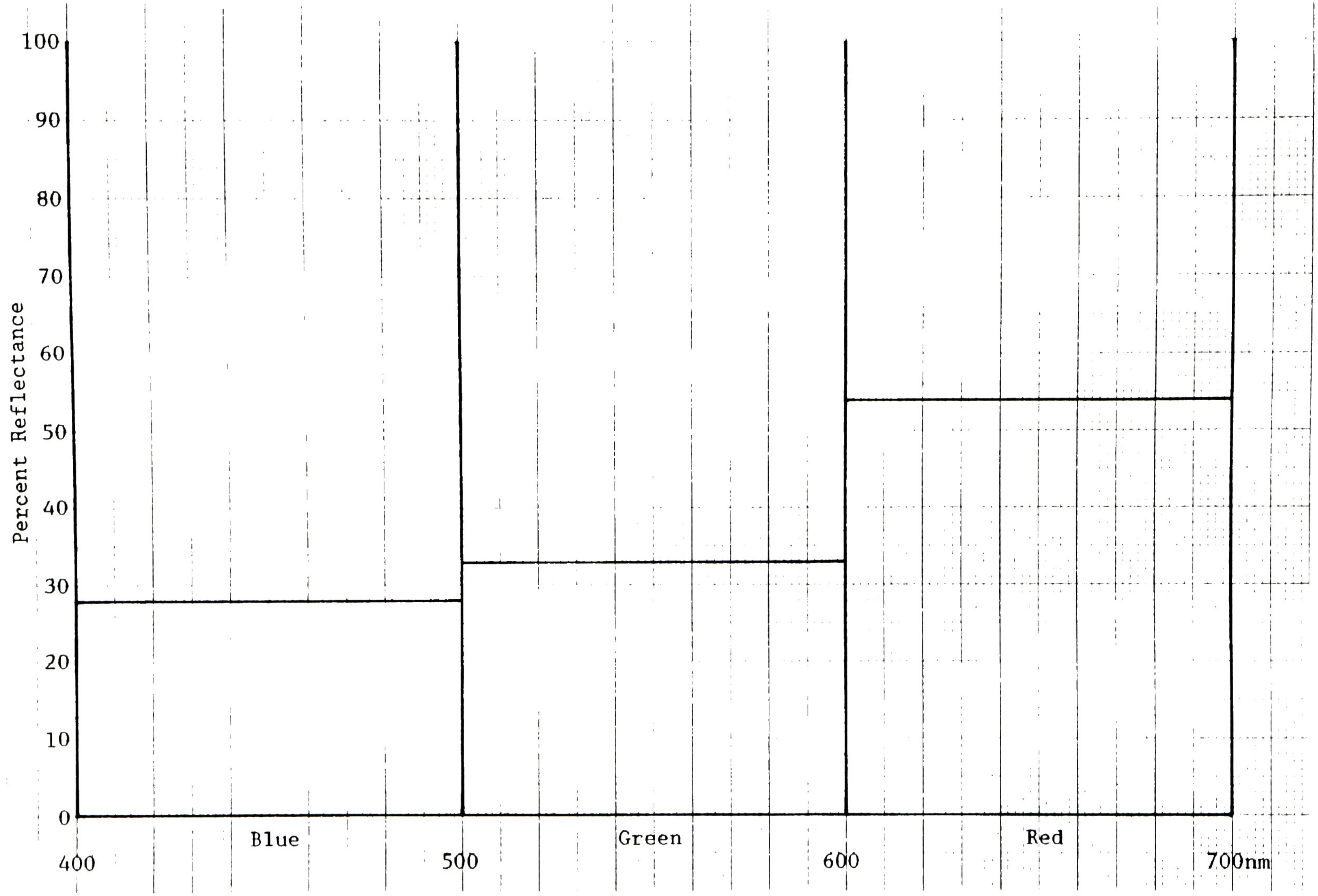


Figure 27. Average reflectance curve for Tint Configuration F[1].

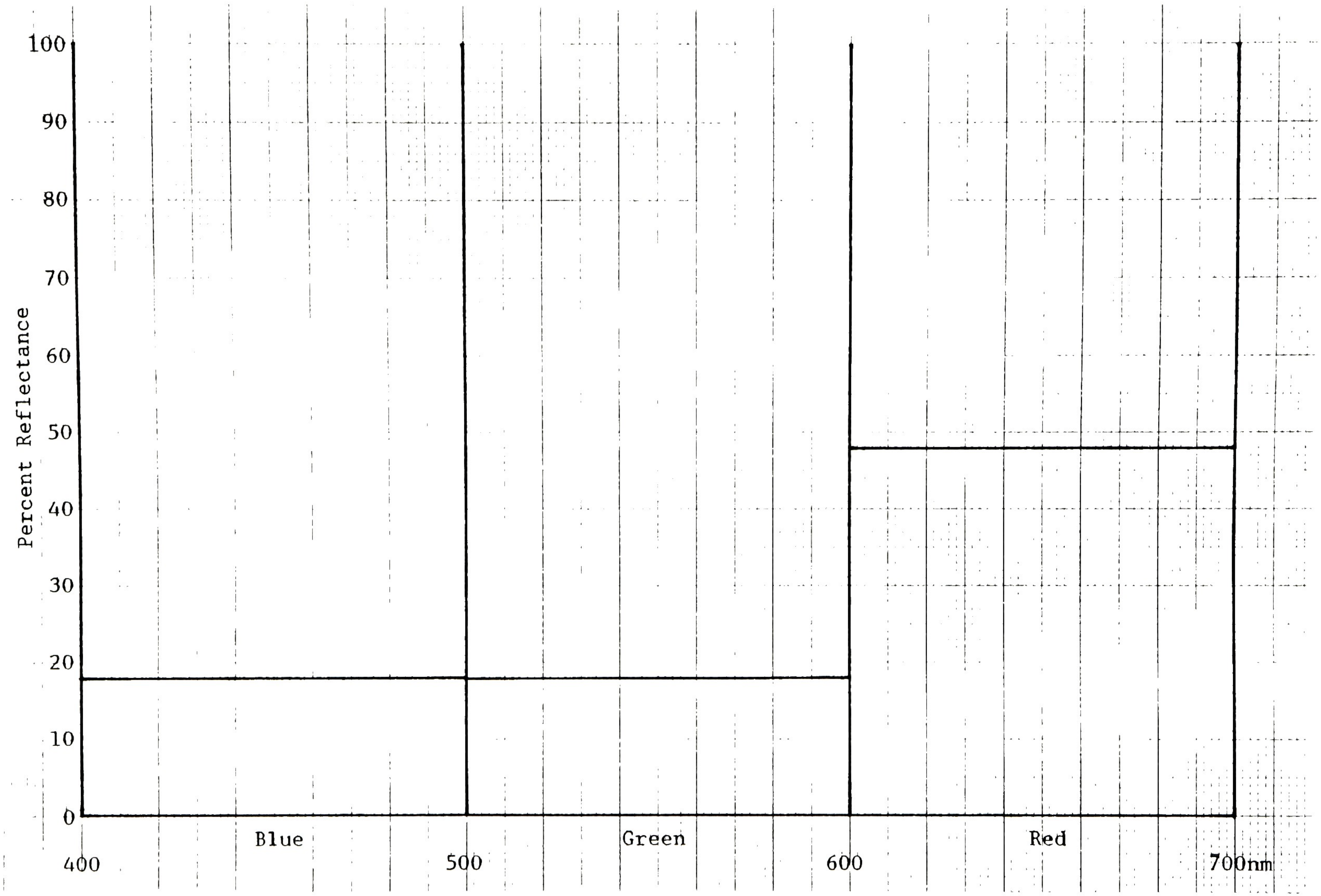


Figure 28. Average reflectance curve for Tint Configuration F^2.

Table 15.

Average transmission visual filter density based on nine samplings.
Tint Configuration: A^1, A^2, B^1, B^2

VISUAL FILTER

Tint:	A^1	A^2	B^1	B^2
	.22	.28	.29	.41
	.22	.28	.29	.41
	.22	.27	.30	.40
	.22	.27	.30	.41
	.22	.28	.29	.41
	.22	.27	.29	.41
	.22	.28	.30	.41
	.22	.28	.29	.40
	.22	.27	.29	.41
Total:	1.98	2.48	2.64	3.67
	÷ 9	÷ 9	÷ 9	÷ 9
	.22	.28	.29	.41
-Film	-.04	-.04	-.04	-.04
Average	.18	.24	.25	.37

Table 16.

Average transmission visual filter density based on nine samplings.
Tint Configuration: C^1, C^2, D^1, D^2

VISUAL FILTER

Tint:	C^1	C^2	D^1	D^2
	.19	.23	.27	.37
	.19	.23	.27	.37
	.19	.23	.27	.37
	.20	.23	.27	.37
	.19	.23	.27	.37
	.20	.23	.27	.36
	.19	.23	.27	.37
	.20	.23	.27	.37
	.19	.23	.27	.37
Total:	1.74	2.07	2.43	3.32
	÷ 9	÷ 9	÷ 9	÷ 9
	.19	.23	.27	.37
-Film	-.04	-.04	-.04	-.04
Average:	.15	.19	.23	.33

Table 17.

Average transmission visual filter density based on nine samplings.
Tint Configuration: E^1, E^2, F^1, F^2

VISUAL FILTER

Tint:	E^1	E^2	F^1	F^2
	.19	.22	.26	.32
	.19	.22	.26	.32
	.19	.21	.26	.33
	.19	.21	.26	.32
	.19	.22	.26	.32
	.18	.21	.26	.33
	.19	.22	.26	.32
	.19	.22	.26	.33
	.19	.22	.26	.32
Total:	1.70	1.95	2.34	2.91
	÷ 9	÷ 9	÷ 9	÷ 9
	.19	.22	.26	.32
-Film	-.04	-.04	-.04	-.04
Average:	.15	.18	.22	.28

Table 18.

Average reflective visual filter density based on nine samplings.
Tint Configuration: A^1, A^2, B^1, B^2

	VISUAL FILTER			
Tint:	A^1	A^2	B^1	B^2
	.51	.63	.65	.88
	.51	.63	.65	.88
	.51	.64	.65	.88
	.51	.63	.65	.86
	.51	.64	.65	.87
	.51	.64	.64	.87
	.51	.62	.65	.85
	.51	.62	.65	.86
	.51	.64	.65	.87
Total:	4.59	5.69	5.84	7.82
	÷ 9	÷ 9	÷ 9	÷ 9
	.51	.63	.65	.87
-Paper	-.15	-.15	-.15	-.15
Average:	.36	.48	.50	.72

Table 19.

Average reflective visual filter density based on nine samplings.
Tint Configuration: C^1, C^2, D^1, D^2

VISUAL FILTER

Tint:	C^1	C^2	D^1	D^2
	.44	.48	.57	.71
	.44	.48	.57	.71
	.44	.48	.57	.72
	.45	.48	.57	.71
	.45	.48	.57	.71
	.45	.48	.57	.72
	.44	.48	.57	.72
	.44	.48	.57	.72
	.44	.48	.58	.72
Total:	3.99	4.32	5.14	6.44
	÷ 9	÷ 9	÷ 9	÷ 9
	.44	.48	.57	.72
-Paper:	-.15	-.15	-.15	-.15
Average:	.29	.33	.42	.57

Table 20.

Average reflective visual filter density based on nine samplings.
Tint Configuration: E^1, E^2, F^1, F^2

VISUAL FILTER

Tint:	E^1	E^2	F^1	F^2
	.47	.51	.58	.73
	.47	.52	.57	.73
	.46	.52	.57	.73
	.46	.51	.57	.73
	.47	.52	.58	.73
	.47	.52	.58	.73
	.47	.51	.58	.74
	.47	.51	.58	.73
	.47	.52	.58	.73
Total:	4.21	4.64	5.19	6.58
	÷ 9	÷ 9	÷ 9	÷ 9
	.47	.52	.58	.73
-Paper:	-.15	-.15	-.15	-.15
Average:	.32	.37	.43	.58

Table 21.

Value for "n" based on visual filter readings.
Tint Configuration: A^1-F^1 and A^2-F^2

"N" VALUES

Tint:	A^1	A^2	B^1	B^2
"n":	2.4	2.4	2.2	2.1
Tint:	C^1	C^2	D^1	D^2
"n":	2.2	1.7	1.9	1.7
Tint:	E^1	E^2	F^1	F^2
"n":	2.6	2.5	2.2	2.4

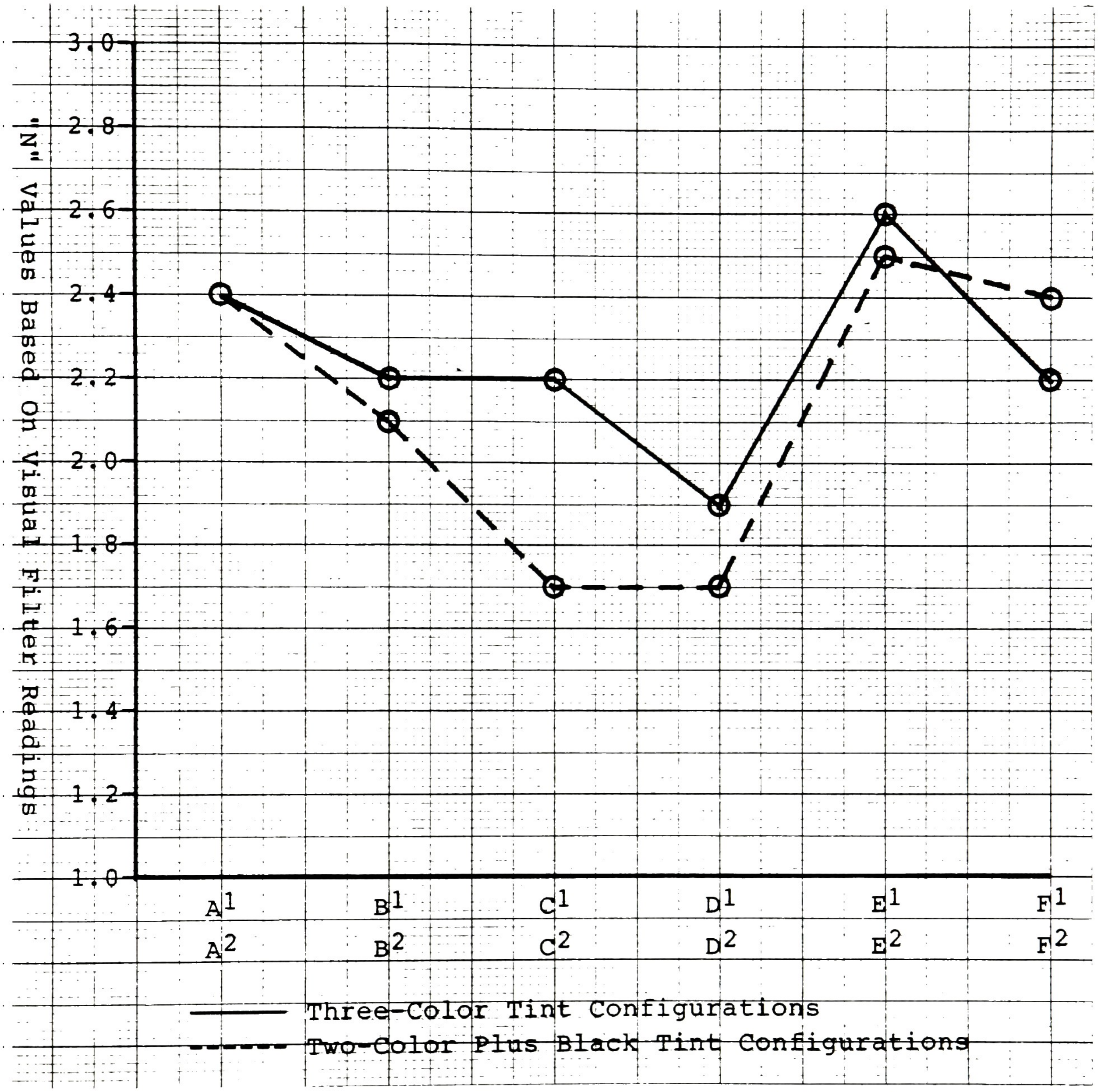


Figure 29. Graph plotting values for "n" against tint configuration.

CHAPTER SEVEN

DISCUSSION OF RESULTS

Average Reflectance Curves

The average reflectance curves for the solid ink densities were as expected. The yellow ink (Figure 13) is most efficient, it reflects almost all of the green and red bands while absorbing most of the blue band. The magenta ink (Figure 14) absorbs most of the green band, however it also absorbs most of the blue band and some of the red band. The cyan ink (Figure 15) absorbs most of the red band and reflects or transmitts most of the blue band, as it should. However, the cyan ink also absorbs a great deal of the green band. As expected, of the three transparent process colored inks used in this experiment, the magenta ink is the most deficient, while the yellow ink is the most efficient.

The black ink (Figure 16) used absorbs all three bands equally, reflecting only three percent from each of the three bands. Since this black absorbs all three bands equally, it should be an efficient substitute in the GCR transformations.

Figures 17-28 are the average reflectance curves for the twelve tint configurations. They are graphed and will be used as a reference for forthcomming discussion.

Quick Review

A quick review of the experiment and its purpose will be usefull here. The experiment is designed so that a tint configuration made up of three process colors is generated and an "n" value calculated. This tint configuration is then analyzed on an eletronic dot generating scanner to determine its two-color plus black hue and saturation equivalent. An "n" value is also calculated for this two-color plus black tint configuration. The "n" values are calculated using the Yule Nielsen Equation, based on the transmission visual filter density readings of an unlaminated negative matchprint versus the reflective visual filter density readings of the same negative matchprint after it is laminated to the base material.

The hue and saturation for the two configurations should be equal, but the lightness should differ. Further, the lightness of the two-color plus black tint configuration should be a closer match to the original (it will have a lower "n" value) than the three-color tint configuration. The original in this experiment is the unlaminated negative matchprint.

The two-color plus black configuration should have a lower "n" value than the three-color configuration because it should have a lower amount of dot coverage. A lower amount of dot coverage would allow for less chance of light scatter and trapment by the ink resulting in a lower "n" value.

Results

Of the six pairs of "n" values, four are lower, one is equal, and one is greater for the two-color plus black tint configurations versus the three-color tint configurations. This is shown in Graph 29. The two-color plus black tint configurations in sets B, C, D, and E have lower "n" values than their corresponding three-color tint configurations. The two-color plus black tint configuration and its corresponding three-color tint configuration in set A have equal "n" values. Finally, in set F, the "n" value for the two-color plus black tint configuration is higher than the "n" value for the three-color tint configuration.

Experimental Errors

There are two specific problems with the experiment that need to be addressed:

1) For this experiment to work successfully, it is

necessary that the hue and saturation for each set be equal and only the lightness differ. In this experiment, the hues were the same but the saturations were different for each of the six sets of tint configurations. In this experiment, when two configurations have the same dominant wide band reflectance, they are said to have the same hue. In set A, both the three-color tint configuration A^1 and its corresponding two-color plus black tint configuration A^2 have a blue hue (Figure 17, Figure 18). In set B, both configurations, B^1 and B^2, also have a blue hue (Figure 19, Figure 20). In set C, both configurations, C^1 and C^2, have a green hue (Figure 21, Figure 22). In set D, both configurations, D^1 and D^2, also have a green hue (Figure 23, Figure 24). Finally, set E, E^1 and E^2 (Figure 25, Figure 26), and set F, F^1 and F^2 (Figure 27, Figure 28), have red hues.

The saturation within each set however is different. The blue hue in A^2 (Figure 18) is more saturated than its corresponding blue hue in A^1 (Figure 17). Likewise, the blue hue in B^2 (Figure 20) is more saturated than its corresponding blue hue in B^1 (Figure 19). The same holds true in each of the four remaining sets of tint configurations. In each case, the two-color plus black tint configuration (x^2) is higher in saturation than its corresponding three color tint configuration (x^1).

2)A second problem with the experiment is that the GCR transformations (two-color plus black calculations) did not result in significant dot coverage reductions. In sets C, E and F, only the least dominant colored ink was replaced with black, the other two inks were not reduced at all. In sets A, B and D, the black ink replaced the least dominant colored ink while reducing one of the other two colored inks. In none of the six configurations were all three colored inks affected by the 100% GCR transformations.

A^1	11% yellow 19% magenta 31% cyan 61% = 2.4 "n" value	A^2	13% black 13% magenta 31% cyan 57% = 2.4 "n" value
B^1	19% yellow 31% magenta 41% cyan 91% = 2.2 "n" value	B^2	23% black 19% magenta 41% cyan 83% = 2.1 "n" value
C^1	19% yellow 11% magenta 31% cyan 61% = 2.2 "n" value	C^2	19% yellow 10% black 31% cyan 60% = 1.7 "n" value
D^1	31% yellow 19% magenta 41% cyan 91% = 1.9 "n" value	D^2	28% yellow 23% black 41% cyan 92% = 1.7 "n" value
E^1	19% yellow 31% magenta 11% cyan 61% = 2.6 "n" value	E^2	19% yellow 31% magenta 10% black 60% = 2.5 "n" value
F^1	31% yellow 41% magenta 19% cyan 91% = 2.2 "n" value	F^2	31% yellow 41% magenta 19% black 91% = 2.4 "n" value

In set A, the three-color tint configuration (A^1) has a 61% total dot coverage and its corresponding two-color plus black tint confiuration (A^2) has a 57% total dot coverage; however, the "n" values for these two are identical. In set B, the three-color tint configuration (B^1) contains a 91% total dot coverage and its two-color plus black tint configuration (B^2) has an 83% total dot coverage. The "n" value for B^1 is 2.2, the "n" value for B^2 is 2.1.

In set C, the three-color tint configuration (C^1) has a 61% total dot coverage and its corresponding two-color plus black tint configuration (C^2) has a 60% total dot coverage. The "n" value for C^1 is 2.2, the "n" value for C^2 is 1.7. In set D, the three-color tint configuration (D^1) has a 91% total dot coverage and its corresponding two-color plus black tint configuration (D^2) has a 92% total dot coverage. The "n" values for set D are 1.9 and 1.7, respectively. In this instance, a one percent <u>increase</u> in dot coverage resulted in a .2 "n" value <u>decrease</u>.

In set E, the three-color configuration (E^1) has a 61% total dot coverage and its corresponding two-color plus black tint configuration (E^2) has a 60% total dot coverage. A one percent decrease in total dot coverage here resulted in a .1 "n" value decrease. In set F, the three-color tint configuration (F^1) has a 91% dot coverage and its corresponding two-color plus black tint configuration has a 91% dot coverage. In this set, the total dot coverages are the same but the two-color plus black tint configuration (F^2) has a .2 higher "n" value than its corresponding three-color tint configuration (F^1).

The only two sets of configurations with a dot coverage reduction of more than one percent were sets A and B. Set A had a four percent dot coverage reduction from its three-color configuration to its two-color plus black configuration, but had no change in "n" value. Set B had an eight percent dot coverage reduction from its three-color configuration to its two-color plus black configuration and an "n" value reduction of only .1. In the four other sets, C, D, E, and F, there was little or no change in the percent dot coverage from the three-color to the two-color plus black tint configurations.

CHAPTER EIGHT

SUMMARY & CONCLUSIONS

Eventhough it is true that in four of the six sets the "n" values are lower for the two-color plus black configurations, it is difficult to support the hypothesis due to the two experimental errors. 1) The experiment does not involve comparing configurations of the same hue and saturation and; 2) the percent dot coverage differences are so minute that it is difficult to associate any "n" value decrease directly with that of percent dot coverage.

As mentioned in the methodology, the 100% GCR transformations were performed on an electronic dot generating scanner using the scanner's GCR function. Since the experiment, more research focussed primarily on this scanner's GCR function has been done and two key findings should be noted.

1) The people this author spoke with regarding their scanner's GCR capabilities believe that GCR should not be used for all separations. In particular, these professionals believe that GCR does not work well on colors that are low in saturation. They believe GCR works best in instances where there is more ink on paper, in colors that

are highly saturated. Unfortunately, the colors used in this experiment are low in saturation.

2) Additional literature cited regarding this scanner's GCR capabilities emphasizes the point that GCR may behave a little differently than most people think it does. For example, GCR may not affect all three colors in the reproduction. It may affect only one or two of the colors. In Dr. Eggert Jung's TAGA paper "Programmed And Complementary Color Reduction", Dr. Jung states that the "dominant inks for a color value have to be largely maintained to secure the desired color mixture."[1] Later in his paper he goes on to say that "depending on the printed color one or two chromatic inks are afflicted."[2]

In this experiment, only one or two of the inks were affected by the GCR transformations, refer back to page 75. Based on Dr. Jung's paper and on the results obtained in this experiment, it does appear that GCR behaves a little differently than some people may think it does.

FOOTNOTES FOR CHAPTER EIGHT

[1]Dr. Eggert Jung, "Programmed And Complementary Color Reduction," Technical Association of the Graphic Arts, (1984 TAGA Proceedings), p.137.

[2]Ibid., p.140.

CHAPTER NINE

RECOMMENDATIONS FOR FURTHER STUDY

Since there are some problems with this experiment, it would seem that correcting these specific problems and redoing the experiment would be the most logical recommendation. Specifically, there are two recommendations for further study centered around the existing experiment:

1) Redo the experiment making sure that the two-color plus black tint configurations have the same hue and saturation as their corresponding three-color tint configurations. A simple check prior to the actual experiment is all that is necessary. It would also be feasible to choose a three-color tint configuration out of a color atlas and then visually find its two-color plus black tint configuration match. Doing it this way eliminates the need for a scanner.

2) Redo the experiment choosing different three-color tint configurations. In particular, choose colors that have more percent dot coverage, colors that are more saturated.

In the course of this experiment a topic relating to "n" values came to mind. It seems that past research regarding "n" values has predominately been done with the black ink only. Would a 40% dot of black ink have the same "n" value as a 40% dot of magenta ink? What about a 40% dot of cyan ink, or a 40% dot of magenta ink? An experiment could be done to answer any one of these three questions.

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APPENDICES

APPENDIX A

APPENDINX A

This experiment does not intend to try and measure color with the visual filter. Determining a single "n" value for a muti-colored configuration by taking readings through each of the four colored filters would get complex. Furthermore, it is not necessary in this experiment.

If an "n" value is determined from a visual filter reading for the original, some number will result. Then if an "n" value is determined from a visual filter reading for the reproduction, another number will result. These two numbers are relative, there is no reason that these numbers can not be derived from visual filter readings of multi-colored tint configurations. This method only simplifies the experiment.

APPENDIX B

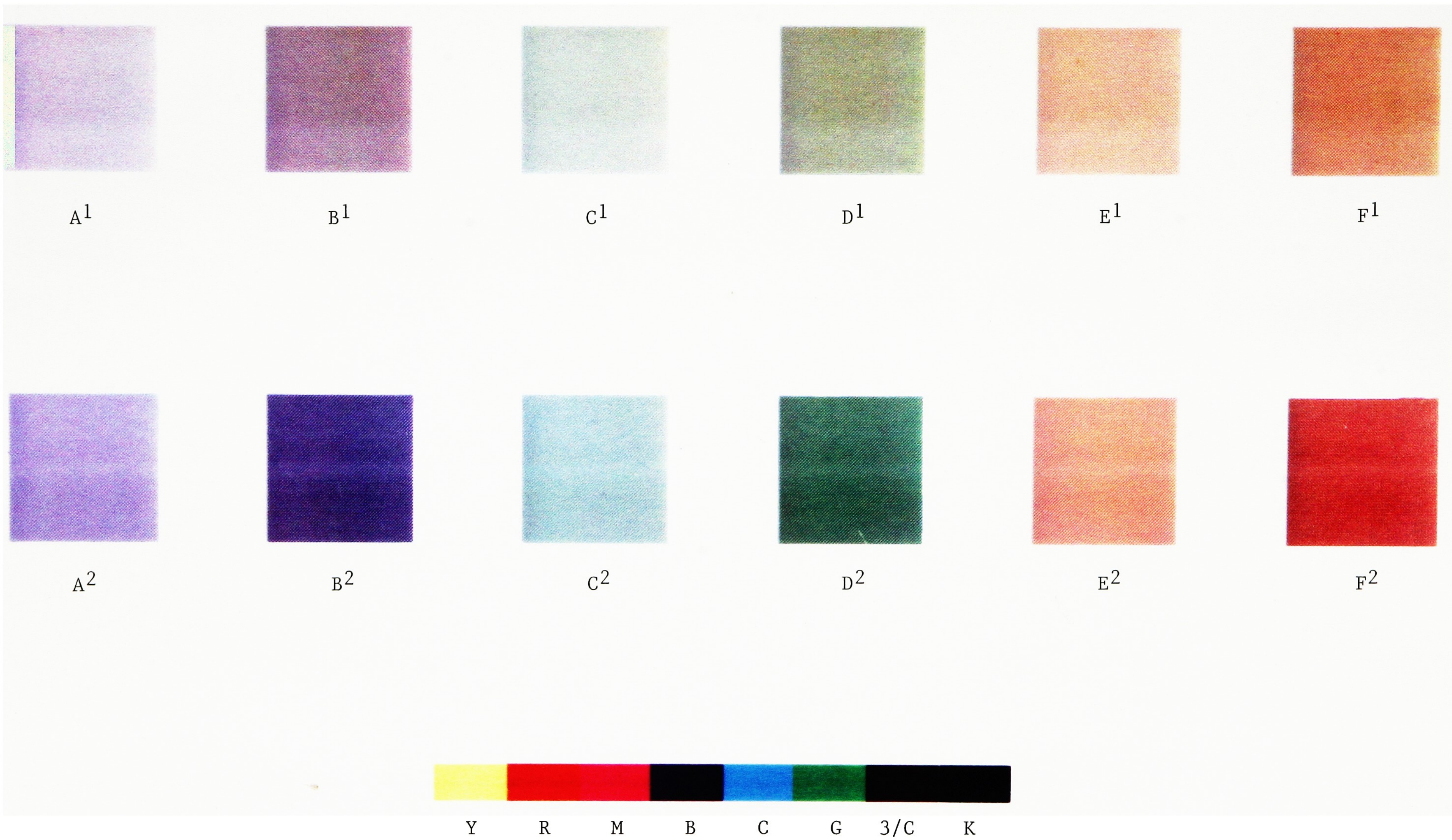
APPENDIX B

Table 22.

"N" values based on blue, green and red filter readings of the 12 tint configurations.

	BLUE FILTER	GREEN FILTER	RED FILTER
A^1	3.3	2.2	1.8
A^2	3.4	2.7	1.7
B^1	3.3	1.9	1.6
B^2	2.6	2.1	1.3
C^1	3.0	2.0	1.8
C^2	2.0	1.9	1.6
D^1	3.3	1.7	1.5
D^2	2.4	1.6	1.3
E^1	3.6	1.7	1.6
E^1	3.0	1.5	1.4
F^1	3.9	1.4	1.4
F^2	4.8	1.6	1.3

APPENDIX C



NOTE*: This sample is a four-color zerox copy of the original matchprint proof. It is not an exact color representation and should be used only for reference.